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Guide for Conducting Treatability Studies under CERCLA

PEI Associates, Inc., Cincinnati, OH

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GUIDE FOR CONDUCTING TREATABILITY STUDIES UNDER CERCLA

INTERIM FINAL

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
CINCINNATI, OHIO 45268

AND

OFFICE OF EMERGENCY AND REMEDIAL RESPONSE
WASHINGTON, D.C. 20460

DISCLAIMER

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

The purpose of this guide is to provide information on conducting treatability studies. It describes a three-tiered approach that consists of 1) laboratory screening, 2) bench-scale testing, and 3) pilot-scale testing. It also presents a protocol for conducting treatability studies in a systematic and stepwise fashion for determination of the effectiveness of a technology (or combination of technologies) in remediating a CERCLA site. The intended audience for this guide comprises Remedial Project Managers, responsible parties, contractors, and technology vendors.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

ABSTRACT

Systematically conducted, well-documented treatability studies are an important component of the remedial investigation/feasibility study (RI/FS) process and the remedial design/remedial action (RD/RA) process under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). These studies provide valuable site-specific data necessary to aid in the selection and implementation of the remedy. This guide, which is being issued as an Interim Final, focuses on treatability studies conducted in support of remedy selection [i.e., pre-Record of Decision (ROD)]; treatability studies in support of remedy implementation (i.e., post-ROD) will be addressed when the document is issued in final form.

The guide describes a three-tiered approach for conducting treatability studies that consists of 1) laboratory screening, 2) bench-scale testing, and 3) pilot-scale testing. Depending on the information gathered during site characterization and technology screening and the data gaps that exist, treatability studies may begin with any tier (e.g., bench-scale testing) and may skip tiers that are not needed (e.g., laboratory screening followed by pilot-scale testing).

The guide also presents a stepwise approach or protocol for conducting treatability studies for determination of the effectiveness of a technology (or combination of technologies) in remediating a CERCLA site. The steps include:

- Establishing data quality objectives
- Selecting a contracting mechanism
- Issuing the Work Assignment
- Preparing the Work Plan
- Preparing the Sampling and Analysis Plan
- Preparing the Health and Safety Plan
- Conducting community relations activities
- Complying with regulatory requirements
- Executing the study
- Analyzing and interpreting the data
- Reporting the results

The intended audience for this guide comprises Remedial Project Managers, responsible parties, contractors, and technology vendors.

This document covers the period from June 1989 to September 1989, and work was completed as of November 1989.

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ABBREVIATIONS

AA	atomic absorption
AAR	Applications Analysis Report
ANOVA	analysis of variance
ANS	American Nuclear Society
ARAR	applicable or relevant and appropriate requirement
ARCS	Alternative Remedial Contracts Strategy
ASTM	American Society for Testing and Materials
ATTIC	Alternative Treatment Technology Information Center
BBS	OSWER Electronic Bulletin Board System
BOM	U.S. Bureau of Mines
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (aka Superfund)
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
COLIS	Computerized On-Line Information Service
CRP	Community Relations Plan
DOT	Department of Transportation
DQO	data quality objective
EP tox	extraction procedure toxicity
EPA	U.S. Environmental Protection Agency
FR	Federal Register
FS	feasibility study
FSP	Field Sampling Plan
GC	gas chromatography
HSL	Hazardous Substance List
HSP	Health and Safety Plan
HSWA	Hazardous and Solid Waste Amendments of 1984
ICP	inductively coupled plasma
KPEG	potassium polyethylene glycolate
MS	mass spectrometry
MSDS	material safety data sheet
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NIOSH	National Institute for Occupational Safety and Health
NPL	National Priorities List
OERR	Office of Emergency and Remedial Response
ORD	Office of Research and Development
OSC	On-Scene Coordinator
OSHA	Occupational Safety and Health Administration
OSW	Office of Solid Waste
OSWER	Office of Solid Waste and Emergency Response
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
QAPjP	Quality Assurance Project Plan

ABBREVIATIONS (continued)

QA/QC	quality assurance/quality control
RA	remedial action
RCRA	Resource Conservation and Recovery Act of 1976
RD	remedial design
RD&D	research, development, and demonstration
REM	Remedial Engineering Management
RFP	request for proposal
RI	remedial investigation
ROC	Regional Offsite Contact
ROD	Record of Decision
RP	responsible party
RPM	Remedial Project Manager
RREL	Risk Reduction Engineering Laboratory
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act of 1986
SITE	Superfund Innovative Technology Evaluation
SOP	standard operating procedure
START	Superfund Technical Assistance Response Team
TCLP	toxicity characteristic leaching procedure
TOC	total organic carbon
TOX	total organic halogen
TSDF	treatment, storage, or disposal facility
USCG	United States Coast Guard
USPS	United States Postal Service
WERL	Water Engineering Research Laboratory
XRF	X-ray fluorescence

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We sincerely hope we have not overlooked anyone who participated in the development of this guide.

SECTION 1

INTRODUCTION

1.1 BACKGROUND

Under the Superfund Amendments and Reauthorization Act of 1986 (SARA), the U.S. Environmental Protection Agency (EPA) is required to select remedial actions involving treatment that "permanently and significantly reduces the volume, toxicity, or mobility of the hazardous substances, pollutants, and contaminants" [Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Section 121(b)].

Selection of remedial actions involves several risk management decisions. Uncertainties with respect to performance, reliability, and cost of treatment alternatives underscore the need for well-planned, well-conducted, and well-documented treatability studies, as evident in the following quote from A Management Review of the Superfund Program (EPA 1989a):

> *"To evaluate the application of treatment technologies to particular sites, it is essential to conduct laboratory or pilot-scale tests on actual wastes from the site, including, if needed and feasible, tests of actual operating units prior to remedy selection. These 'treatability tests' are not currently being performed at many sites to the necessary extent, or their quality is not adequate to support reliable decisions."*

Treatability studies provide valuable site-specific data necessary to support Superfund remedial actions. They serve two primary purposes: 1) to aid in the selection of the remedy, and 2) to aid in the implementation of the selected remedy. Treatability studies conducted during the remedial investigation/feasibility study (RI/FS) phase indicate whether a given technology can meet the expected cleanup goals for the site, whereas treatability studies conducted during the remedial design/remedial action (RD/RA) phase establish the design and operating parameters for optimization of technology performance. Although the purpose and scope of these studies differ, they complement one another (i.e., information obtained in support of remedy selection may also be used to support the remedy design).

Historically, treatability studies have been delayed until after the Record of Decision (ROD) has been signed. Conducting treatability studies earlier in the remedial action process should serve to reduce the uncertainties associated with selecting the remedy, provide a sounder basis for the

ROD, and possibly facilitate negotiations with responsible parties without lengthening the overall remedial action schedule for the site. Because treatability studies may be expensive and time-consuming, however, the economies of cost and time should be taken into consideration when planning treatability studies in support of the various phases of the program.

1.2 PURPOSE AND SCOPE

This guide presents information on conducting treatability studies under CERCLA. The purpose of the document is to facilitate efficient planning, execution, and evaluation of treatability studies and to ensure that the data generated can support remedy selection and implementation.

For purposes of this document, it is assumed that the reader has already identified candidate technologies for remediating the site. The questions of whether to conduct treatability studies, what level of testing is appropriate, and how to proceed are addressed herein.

1.3 INTENDED AUDIENCE

This document is intended for use by Remedial Project Managers (RPMs), responsible parties (RPs), contractors, and technology vendors. Each has different roles in conducting treatability studies under CERCLA, as described here.

1.3.1 Remedial Project Managers

Remedial Project Managers are responsible for project planning and oversight. Their role in treatability investigations is dependent upon the designated lead agency (Federal, State, or private). Their activities generally include scoping the treatability study, establishing the data quality objectives, selecting a contractor, issuing a work assignment, overseeing the execution of the study, and informing or involving the public as appropriate.

1.3.2 Responsible Parties

Currently, responsible parties conduct roughly half of all onsite work under the Superfund program, and the EPA intends to expand its use of enforcement measures and settlement procedures provided under SARA to promote even more private-party cleanups in the future. At enforcement sites, RPs are responsible for planning and executing treatability studies under Federal or State oversight.

1.3.3 Contractors/Technology Vendors

Treatability studies are generally performed by remedial contractors or technology vendors. Their roles in treatability investigations include preparing a work plan and other supporting documents, complying with regulatory requirements, executing the study, analyzing and interpreting the data, and reporting the results.

1.4 USE OF THE GUIDE

1.4.1 Organization of the Guide

The guide is organized into two principal sections: an overview of treatability studies and a step-by-step protocol. Section 2 describes the need for treatability studies and presents a three-tiered approach that consists of 1) laboratory screening, 2) bench-scale testing, and 3) pilot-scale testing. This section also describes the application of the tiered approach to unit operations, treatment trains, and in situ technologies.

Section 3 presents a general approach or protocol for conducting treatability studies. This section contains information on scoping, performing, and reporting the results of treatability studies with respect to the three tiers. Specifically, this section includes information on:

- Establishing data quality objectives (performance goals and associated confidence limits).
- Identifying a qualified contractor and selecting a contracting mechanism.
- Issuing the work assignment, with emphasis on writing the scope of work.
- Preparing the Work Plan, with emphasis on designing the experiment.
- Preparing the Sampling and Analysis Plan, Health and Safety Plan, and Community Relations Plan, with emphasis on addressing issues related specifically to treatability studies.
- Complying with regulatory requirements for testing and residuals management.
- Executing the treatability study, with emphasis on collecting and analyzing samples.
- Analyzing and interpreting the data, including an explanation of statistical analysis techniques.
- Reporting the results in a logical and consistent format.

The text of each subsection presents general information followed by specific details pertaining to the three tiers of testing.

The appendices, which follow Section 3, present sources of treatability information (Appendix A), cost elements associated with treatability studies (Appendix B), characterization parameters for five technology categories (Appendix C), and standard analytical methods for characterizing wastes (Appendix D).

1.4.2 Application and Limitations of the Guide

Treatability studies are an integral part of the remedial planning process. This guide is intended to supplement the information on development, screening, and analysis of alternatives contained in the Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (Interim Final) (EPA 1988a). Data from treatability studies can be used to accept or reject technologies for detailed analysis (laboratory screening) or to assess and compare feasible alternatives in accordance with specified evaluation criteria (bench- and pilot-scale testing).

This guide, which is general in nature, encompasses all waste matrices (soils, sludges, liquids, gases) and all categories of technologies (biological treatment, physical/chemical treatment, immobilization, thermal treatment, and in situ treatment). Currently, the guide addresses only treatability studies conducted in support of remedy selection (i.e., pre-ROD); treatability studies in support of remedy implementation (i.e., post-ROD) will be addressed when the document is issued in final form. Companion documents on treatability protocols for soil washing, solidification/stabilization, and aerobic biodegradation of organics in soil are being developed and will be available in fiscal year 1990; other technology-specific protocols are also planned.

In an effort to be concise, supporting information in other readily available guidance documents is referenced throughout the guide rather than repeated. Details on the preparation of the Sampling and Analysis Plan (which includes a Field Sampling Plan and a Quality Assurance Project Plan), the Health and Safety Plan, and the Community Relations Plan, for example, are not given in the guide.

The available information on the cost and time for performing treatability studies is sparse. These data should be included in future treatability study reports, as described in Subsection 3.12, to provide more accurate figures for planning purposes.

This document was drafted and reviewed by representatives from EPA's Office of Emergency and Remedial Response (OERR), Office of Research and Development (ORD), and the Regional offices, as well as by contractors who conduct treatability studies. Comments obtained during the course of the peer review process have been integrated and/or addressed throughout this guide. The document is being issued as an Interim Final to prompt both use and comment on the approach and methodology presented here. Readers are invited to send their comments or suggestions on the guide by June 1, 1990, to the following address:

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SECTION 2

OVERVIEW OF TREATABILITY STUDIES

This section presents an overview of treatability studies under CERCLA and provides a decision tree with examples of the application of treatability studies to the RI/FS and remedy selection process. Subsection 2.1 summarizes the need for and goals of treatability studies during the RI/FS (or remedy evaluation) phase. Subsection 2.2 provides details on the different tiers of treatability studies, including laboratory screening, bench-scale testing, and pilot-scale testing. Subsection 2.3 presents examples of how and when to apply the tiered approach.

2.1 TREATABILITY STUDIES IN THE RI/FS PROCESS

As discussed in EPA's RI/FS interim final guidance (EPA 1988a), site characterization and treatability investigations are two of the main components of the RI/FS process. As site and technology information is collected and reviewed, additional data needs for evaluating alternatives are identified. Treatability studies and/or detailed site characterization studies may be required to fill in these data gaps.

In the absence of data in the available technical literature or treatability data bases, treatability studies can provide the critical performance and cost information needed to evaluate and select treatment alternatives. The RI/FS interim final guidance specifies nine evaluation criteria for use in the detailed analysis of alternatives; treatability studies can address seven of these criteria:

1) Overall protection of human health and the environment
2) Compliance with applicable or relevant and appropriate requirements (ARARs)
3) Implementability
4) Reduction of toxicity, mobility, or volume
5) Short-term effectiveness
6) Cost
7) Long-term effectiveness

Community and State acceptance, the other two criteria affecting the evaluation and selection of the remedial alternative, can influence the decision to conduct treatability studies on a particular technology.

Treatability studies involve testing one or more technologies in the laboratory or field to gain qualitative and/or quantitative information for assessing their performance on specific wastes at the site. Generally, treatability testing of alternative technologies can begin during the initial phases of site characterization and technology screening, as shown in Figure 1. Laboratory screening, bench-scale testing, or pilot-scale testing must be scoped and initiated as early as possible (i.e., during the scoping phase) to keep the RI/FS on schedule and within budget. Treatability testing can continue through the pre-ROD remedy evaluation and into the post-ROD remedy implementation phase of a Superfund site remediation.

2.1.1 Determining the Need for Treatability Studies

After information on the physical and chemical characteristics of the waste has been obtained, a literature survey of remedial technologies is performed. Technical information resources, including information from reports and guidance documents, electronic data bases, and experienced EPA staff are reviewed, and available performance and cost information on each technology is obtained and evaluated with respect to the waste type and site conditions present. Appendix A contains a survey of available information sources.

Based on the results of the literature survey and available site and waste data, remedial technologies are screened to eliminate nonapplicable technologies; potentially and definitely applicable technologies are retained for further consideration. Additional site- and technology-specific data needs are identified for each of the technologies retained for further analysis, and the need to conduct treatability studies on any or all of these technologies is determined.

Treatability studies may be needed for applicable technologies for which no or limited performance information is available in the literature with regard to the waste types and site conditions of concern. The general decision tree presented in Figure 2 illustrates when treatability studies are needed to support the evaluation of an alternative.

The need for treatability studies, the number of alternatives to be evaluated, and the level of treatability testing are all management-based decisions. (Management decision factors to be considered in the treatability study decision process are discussed further in Subsection 2.3.1.) The RPM must determine whether the available data can adequately address all nine of EPA's remedy evaluation criteria. If so, no treatability studies would be needed to evaluate the technology. Similarly, if a candidate technology is not accepted by the community or State, there may be little merit in performing a treatability study to investigate it as an alternative. On the other hand, the results of a treatability study may provide additional information that alleviates community and State concerns regarding an alternative technology. If the collected information does not adequately address EPA's remedy evaluation criteria, the RPM should determine whether the missing data can be obtained from other literature sources before deciding to perform

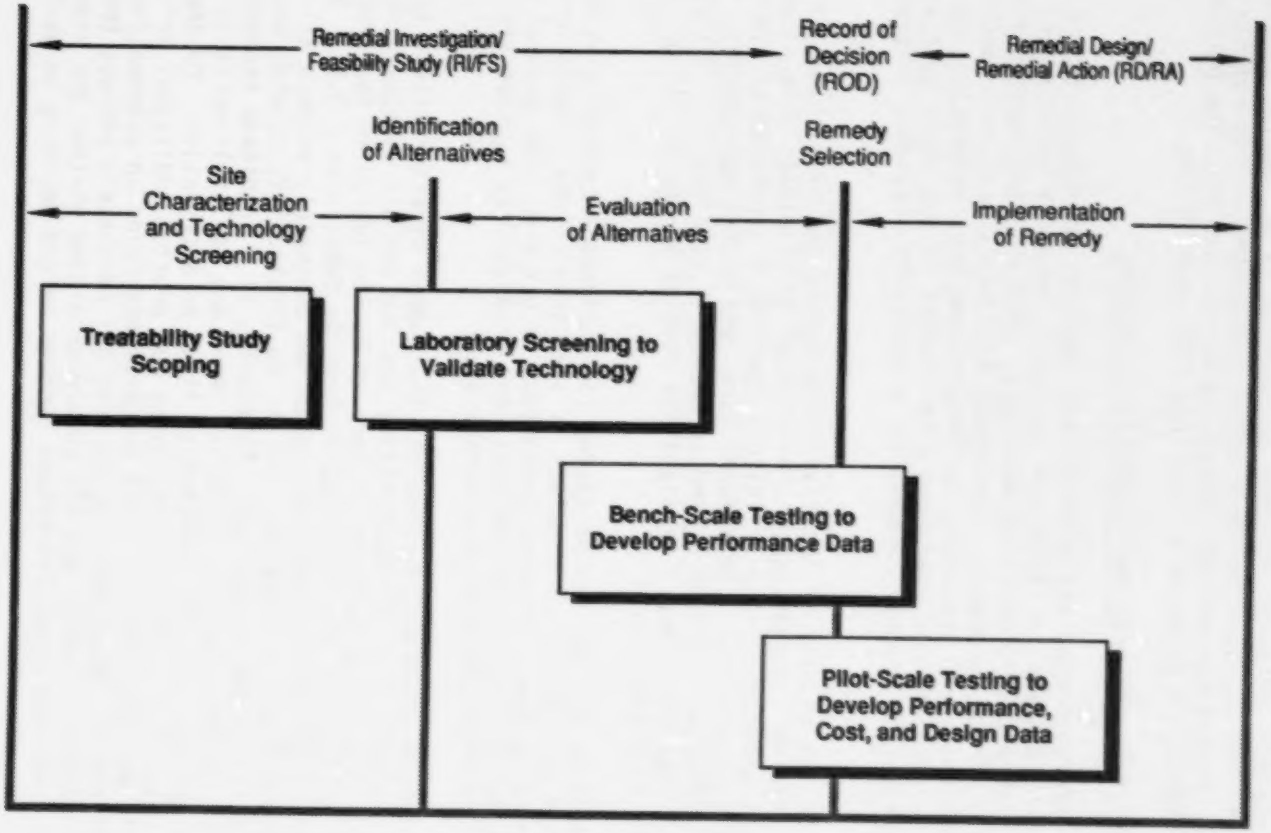

Remedial Investigation/
Feasibility Study (RI/FS)
Record of
Decision
(ROD)
Remedial Design/
Remedial Action (RD/RA)
Identification
of Alternatives
Remedy
Selection
Site
Characterization
and Technology
Screening
Evaluation
of Alternatives
Implementation
of Remedy
Treatability Study
Scoping
Laboratory Screening to
Validate Technology
Bench-Scale Testing to
Develop Performance Data
Pilot-Scale Testing to
Develop Performance,
Cost, and Design Data

Figure 1. The role of treatability studies in the RI/FS and RD/RA process.

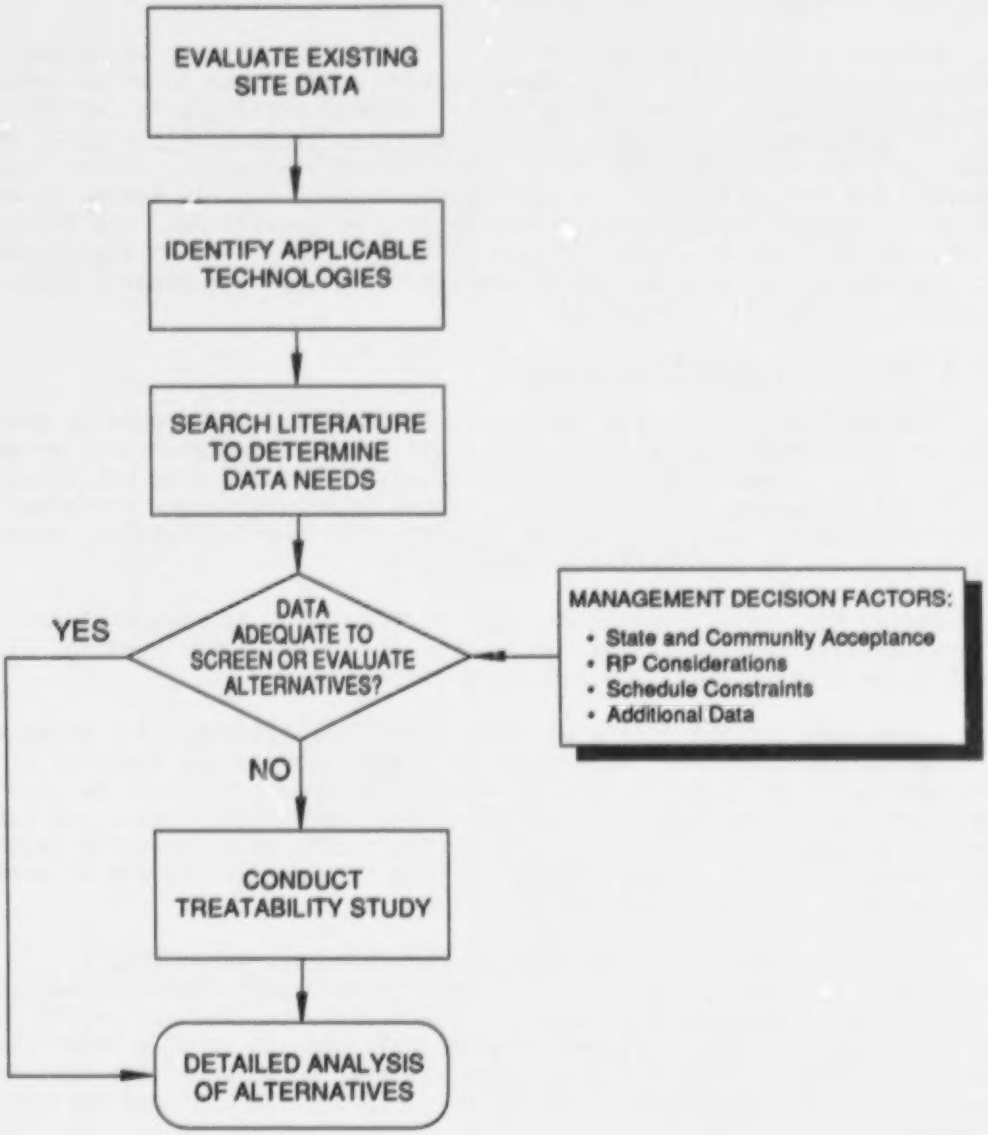

EVALUATE EXISTING SITE DATA
IDENTIFY APPLICABLE TECHNOLOGIES
SEARCH LITERATURE TO DETERMINE DATA NEEDS
DATA ADEQUATE TO SCREEN OR EVALUATE ALTERNATIVES?
YES
NO
MANAGEMENT DECISION FACTORS:
• State and Community Acceptance
• RP Considerations
• Schedule Constraints
• Additional Data
CONDUCT TREATABILITY STUDY
DETAILED ANALYSIS OF ALTERNATIVES

Figure 2. Decision tree showing when treatability studies are needed to support the evaluation and selection of an alternative.

treatability studies. The availability of funds and time also play a significant role in determining the need for treatability studies.

Example 1 illustrates when treatability studies may not be needed in the remedy evaluation phase. This example covers a situation in which information needed to evaluate the technology is readily available in the literature and EPA technology data bases. Consequently, no treatability studies were conducted. In numerous other cases, the site contamination problem is more complex, and information on the performance or cost that is needed to evaluate the treatment technologies may be lacking or nonexistent. In these cases, the decision to conduct treatability studies is not straightforward, and some overall prioritization of activities to meet the project goals, schedule, and budget is required.

2.1.2 Defining Treatability Studies

Treatability studies are laboratory or field tests designed to provide critical data needed to evaluate and, ultimately, to implement one or more technologies. These studies generally involve characterizing untreated wastes and evaluating the performance of the technology under different operating conditions. Depending on the objectives of the treatability testing, the results may be qualitative or quantitative.

During the remedy evaluation phase of the RI/FS, as many as three tiers of treatability testing may be undertaken: 1) laboratory screening, 2) bench-scale testing, and 3) pilot-scale testing.

Laboratory screening is used to establish the validity of a technology to treat an operable unit. Jar tests or beaker studies are examples of this treatability study tier. Screening studies yield data that can be used as indicators of a technology's potential to meet performance goals and can identify parameters for investigation during bench- or pilot-scale testing. They generate little, if any, design or cost data and should not be used as the sole basis for the selection of a remedy.

Bench-scale testing is intended to determine the technology's performance for the operable unit. Bench-top unit operations are indicative of this tier of treatability testing. Bench-scale testing can verify that the technology can meet expected cleanup goals and can provide information in support of remedy evaluation (i.e., that relates to seven of the nine evaluation criteria). Bench-scale testing may also provide cost and design information.

Pilot-scale testing is intended to provide quantitative performance, cost, and design information for remediating an operable unit. This level of study can also produce data required to optimize performance. Testing of a mobile pilot-scale unit operation at the site is indicative of this tier. Because these tests also provide detailed design information, they are most often performed during the remedy implementation phase of a site cleanup. In a few cases, such as for in situ treatments, pilot-scale studies may be necessary during remedy evaluation.

EXAMPLE 1. DETERMINING THE NEED FOR TREATABILITY STUDIES

ABANDONED BATTERY RECLAMATION SITE

Background--

An abandoned battery reclamation site is contaminated primarily with lead. After evaluating site data (including site areal extent, hydrogeology, permeability and chemistry of soil, and depth/extent of lead contamination), the RPM reviews the literature to identify and screen potentially or definitely applicable technologies. During this scoping phase, the RPM decides that immobilization and soil washing are definitely applicable technologies, whereas fluosilicic acid treatment is a potentially applicable technology. At this point, the RPM identifies site- and technology-specific data needs for evaluating the candidate technologies. The RPM must now decide whether to conduct treatability studies on one, two, or all three technologies. Technical and managerial inputs gathered to support the decision include the following:

- Availability of funds and time to conduct treatability studies.
- Adequacy of existing data to address all of the nine evaluation criteria.
- Availability of information in other literature or data bases not already reviewed.
- Acceptance of the candidate technologies by the community and State.

Decision Based on Literature and Existing Data--

The RPM decides that adequate funds and time are available to conduct treatability studies. The literature and data base review yielded relevant performance data on immobilization and soil washing. In fact, a treatability study for evaluation of the performance of soil washing and immobilization processes on soils and battery casings contaminated with lead at a site in a neighboring State is currently underway. Limited information is available on the fluosilicic acid technology, however, as it is young and not well developed. Also, the State has indicated a preference for proven technologies such as immobilization or soil washing, or both. The RPM discusses the technical and nontechnical considerations with the Unit Chief, and they decide that no treatability studies are needed in support of remedy evaluation during the RI/FS. A treatability study in support of remedy implementation, however, is planned for the RD/RA phase.

The three tiers of treatability testing and their attributes are as follows:

1) Laboratory Screening--Jar tests or beaker studies that are performed in the laboratory and are characterized by the following:

   - Relatively low costs
   - Short amounts of time to perform
   - Low levels of quality assurance/quality control (QA/QC)

   Results yield qualitative performance data but no design or cost information.

2) Bench-Scale Testing--Bench-top studies that are performed in the laboratory or field and are characterized by the following:

   - Moderate costs
   - Moderate amounts of time to perform
   - Moderate to high levels of QA/QC

   Results yield quantitative performance data with some design and cost information.

3) Pilot-Scale Testing--Pilot-plant studies that are performed in the field and are characterized by the following:

   - High costs
   - Long amounts of time to perform
   - Moderate to high levels of QA/QC

   Results yield quantitative performance data with detailed design, cost, and process optimization information.

2.1.3 Treatability Study Goals

Setting goals for the treatability study is critical to the ultimate usefulness of the data generated. Goals or objectives must be defined before the treatability study is performed. Each tier of treatability study needs performance goals appropriate to that tier. For example, laboratory screening is often used to answer the question, "Does the mechanism of this technology (physical, chemical, biological, or thermal treatment) work on this waste stream?" It is necessary to define "work" (e.g., set the goal of the study). A pollutant reduction of 50 percent during a jar test may satisfy the test for validity of the process and indicate that further testing at the bench scale is appropriate to determine if the technology can meet the anticipated performance criteria of the ROD.

The ideal goals for technology performance are the cleanup criteria for the operable unit. For several reasons, such as continuing waste analysis and ARARs determination, some cleanup criteria are not finalized until the ROD is signed. Nevertheless, treatability study goals need to be established before the study is performed so that the success of the treatability study can be assessed. In many instances, this may entail an educated guess as to what the final cleanup levels may be. In the absence of set cleanup levels, the RPM can estimate performance goals for the treatability studies based on the following criteria:

- Levels that provide overall protection of human health and the environment
- Levels that are in compliance with ARARs, including land disposal restrictions
- Levels that ensure a reduction of toxicity, mobility, or volume
- Levels acceptable for delisting of the waste
- Levels set by the State or Region for another site with contaminated media with similar characteristics and contaminants

Cleanup criteria directly relate to the final management of the material and dictate the need for other treatment processes to treat the entire waste stream (i.e., treatment trains). These factors must be be considered during the planning and design of the treatability studies and in the overall remedy evaluation and selection. The development of tiered goals for contaminant reduction may be instrumental in fully addressing this issue. For example, if the treatment technology can reduce contaminant levels to 1 ppb, the treated waste can be landfilled with no controls. If a treatment technology only reduces the contaminant level to 5 ppm, the treated waste will have to be disposed of in a landfill permitted under Subtitle C of the Resource Conservation and Recovery Act (RCRA). If the treatment technology only reduces the contaminant level to 50 ppm, the waste will have to be stabilized before its disposition in a RCRA Subtitle C landfill.

2.2 TIERS OF TREATABILITY TESTING

As mentioned earlier in this section, the treatability study process designed to support the investigation, evaluation, and ultimate implementation of treatment alternatives at CERCLA sites comprises three tiers:

1) Laboratory screening
2) Bench-scale testing
3) Pilot-scale testing

Laboratory screening and bench-scale testing are usually employed during remedy evaluation. Pilot-scale testing is generally (but not always) used during remedy implementation.

Each tier of treatability testing has different functional requirements and provides different kinds of information about a treatment technology. Table 1 lists general similarities and differences among the three tiers, including the type of data generated; the analytical level used; the number of critical parameters investigated; the number of replicates required; the study size, usual process type, and waste volume needed; and the typical duration and cost of conducting a study.

TABLE 1. GENERAL COMPARISON OF LABORATORY SCREENING, BENCH-SCALE TESTING, AND PILOT-SCALE TESTING

Tier	Type of data generated	Analytical level[a]	Critical param-eters	No. of repli-cates	Study size	Usual process type	Waste stream volume	Time re-quired	Cost, $
Laboratory screening	Qualitative	I-II	Several	Single/ duplicate	Jar tests or beaker studies	Batch	Small	Hours/ days	10,000-50,000
Bench-scale testing	Quantitative	III-V	Few	Duplicate/ triplicate	Bench-top (some larger)	Batch or continu-ous	Medium	Days/ weeks	50,000-250,000
Pilot-scale testing	Quantitative	III-V	Few	Triplicate or more	Pilot-plant (onsite or offsite)	Batch or continu-ous	Large	Weeks/ months	250,000-1,000,000

[a] Analytical levels are defined in Data Quality Objectives for Remedial Response Activities (EPA 1987a); see Subsection 3.2.

2.2.1 Laboratory Screening

Laboratory screening, the first step in the tiered approach, is designed to establish the validity of an alternative technology quickly and inexpensively. Validity depends on the ability of the technology to achieve performance goals set prior to the screening. If the goals are not attained, the technology is rejected. In the event that all technologies screened are rejected, the RPM should reevaluate the performance goals to determine if they are still appropriate. This level of testing could result in a potentially applicable alternative being rejected or a nonapplicable alternative being retained for further testing. The risk of this occurring is acceptable, however, in light of the cost and time savings associated with laboratory screening.

Type of Data--

In general, laboratory screening provides qualitative data that will be used to evaluate the validity of the technology as a treatment process for an operable unit. No cost or design information will be generated. The RPM, in consultation with management, must determine the overall qualitative data needs based on the intended use of the information and the availability of time and funds.

During laboratory screening, an indicator contaminant is often monitored to determine whether a reduction in toxicity, mobility, or volume is occurring. If a technology appears to meet or exceed the performance goal, it is considered valid and retained for further evaluation. Laboratory screening is also useful for identifying critical parameters for investigation in later bench- and pilot-scale testing.

Analytical Level--

Analytical levels I and II are generally sufficient to screen alternative technologies; however, analytical levels III through V may also have application. (Table 2 in Subsection 3.2 outlines the five analytical levels established by EPA.)

Critical Parameters/Number of Replicates--

Several parameters (e.g., temperature, pH, reaction time) can be investigated during laboratory screening, and each can be evaluated at a few levels over a broad range of values. During laboratory screening, the focus of the investigation of a technology is on screening a large number of parameters to identify those that will be critical for later bench- or pilot-scale investigation.

The laboratory screening tier requires little or no replication (single or duplicate) in most cases. A low level of QA/QC is sufficient because a remedy that is found to be valid will generally undergo bench-scale testing.

Study Size/Process Type/Waste Volume--

Laboratory screening is limited in size and scope to small-scale jar tests and beaker studies performed on the bench-top. This tier will generally involve batch tests and use small-volume samples of the waste stream. For example, laboratory screening of an ion exchange process designed to treat aqueous wastes may require sample volumes on the order of 500 ml per run with only three runs through a column.

Time/Cost--

The duration and cost of laboratory screening depend primarily on the type of technology being investigated and the number of parameters considered. Generally, laboratory screening can be performed within a time range of hours to days at a cost of between $10,000 and $50,000. The cost estimate includes analytical support; however, the time estimate does not consider sample analysis or data validation, as these elements depend on the analytical laboratory used.

The nature of laboratory screening (i.e., its relatively small numbers of samples and replicates, less stringent QA/QC requirements, and minimum reporting requirements) makes it the least costly and time-consuming of the three treatability study tiers.

2.2.2 Bench-Scale Testing

Bench-scale testing, the second step in the tiered approach, is designed to verify whether an alternative technology can meet the performance goals for the site. This tier provides a quantitative evaluation of the performance of a technology as well as some cost and design information. Bench-scale tests can be performed on any technology that is supported in the literature or by laboratory screening data. These tests focus on the critical parameters that have an impact on performance.

Type of Data--

Bench-scale testing provides quantitative data that will be used to assess the performance of a technology for treatment of a particular waste stream. The following are examples of performance evaluations that can be made at the bench-scale:

- Product curing rates, optimum additives, and admixture ratios for immobilization technologies.
- Pretreatment requirements, reaction rates, and optimum flocculant formation conditions for precipitation treatment technologies.
- Contaminant removal efficiencies of soil washing at different throughput rates.

The operational and performance information resulting from bench-scale testing permits more accurate full-scale cost and schedule estimates than can be made based on laboratory screening. Bench-scale tests can provide information needed to size unit operations and to estimate treatment train considerations such as waste mixing and materials handling.

When planning bench-scale testing, the RPM, in consultation with management, must determine the overall quantitative data needs for a technology based on the intended use of the information and the availability of time and funds.

Analytical Level--

Analytical levels III through V are generally necessary to demonstrate technology performance in support of remedy selection. (Table 2 in Subsection 3.2 outlines the five analytical levels established by EPA.)

Critical Parameters/Number of Replicates--

A small number of critical parameters--those that have been identified in the literature or by laboratory screening--are investigated during bench-scale testing. These parameters are evaluated at many levels over a narrow range of values to determine the technology's performance.

The bench-scale testing tier requires duplicate or triplicate replication in most cases. A moderate to high level of QA/QC is generally needed to increase the confidence in the decision that the remedy selected can meet the performance goals for the site.

Study Size/Process Type/Waste Volume--

The size and scope of bench-scale testing is generally limited to studies performed on the bench-top with equipment designed to simulate the basic operation of a treatment process. Bench-scale testing may be conducted as either a batch or continuous process. The waste stream sample volume needed to perform continuous, bench-scale testing of an ion exchange treatment process for an aqueous waste may be on the order of 1 liter per minute for a period of 8 hours (which would require approximately 500 liters of waste).

Time/Cost--

The duration and cost of bench-scale testing depend primarily on the type of technology being investigated, the types of analyses being performed, and the number of replicates required for adequate testing of that technology. Most bench-scale testing can be performed within a time range of days to weeks at a cost of between $50,000 and $250,000. This cost estimate includes analytical support. The estimate of duration, however, covers only the actual performance of the test. It does not include the time required for construction and shakedown of the bench-scale apparatus, as these procedures are specific to the technology being investigated. Neither does the time estimate consider sample analysis or data validation, as these elements depend on the analytical laboratory used.

The increased cost of bench-scale testing compared with laboratory screening is directly related to the more stringent QA/QC requirements and the larger number of samples and replicates to be analyzed.

2.2.3 Pilot-scale Testing

Pilot-scale testing, the final step in the tiered approach, is designed to provide detailed cost, design, and performance data. It yields the most accurate scale-up information of the three tiers. These tests can be performed on any technology that is supported either in the literature or by laboratory screening or bench-scale testing data.

Whereas pilot-scale testing is generally not necessary for evaluation of alternatives in support of remedy selection, innovative technologies or technologies for which limited data are available (e.g., in situ technologies) may require pre-ROD pilot-scale testing to provide data needed to evaluate the technology. Multiple-unit treatment train systems will generally require pilot-scale testing to evaluate the design fully. The ultimate decision as to whether to conduct pilot-scale testing during the RI/FS rests with the RPM and management and will be based on the complexity of the alternative, the existing data, and the availability of time and funds.

If a ROD is written prior to the selection of a final remedy, it will list the alternatives being considered and indicate that the final selection of a remedy will be based on the results of pilot-scale testing of the listed alternatives.

Type of Data--

Pilot-scale testing provides the detailed, quantitative cost, design, and performance data required to optimize the critical parameters. The following issues can be addressed with the data generated by pilot-scale testing:

- Overall performance and cost of the technology
- Design information needed to size unit operations
- Treatment train considerations such as waste mixing and materials handling
- Process upsets and recovery
- Side-stream and residuals generation
- Site-specific considerations, such as heavy equipment access; adequate space for the staging of waste feed, treatment reagents, and residuals; and local availability of equipment.

Pilot-scale testing may also help to identify waste stream characteristics that have the potential to affect the implementability of a technology. For example, physical characteristics of the waste feed may introduce unexpected materials-handling problems. Similarly, chemical characteristics of the waste that are outside of the technology's operating range may require process modifications. Such waste-stream characteristics may not be identified during site characterization or bench-scale testing and may only be discovered during pilot-scale testing.

When planning pilot-scale testing, the RPM, in consultation with management, must determine what the overall quantitative data needs for a technology are. Consideration must be given to the intended use of the information and the availability of time and funds.

Analytical Level--

Analytical levels III through V are generally necessary to demonstrate technology performance in support of remedy selection and implementation. (Table 2 in Subsection 3.2 outlines the five analytical levels established by EPA.)

Critical Parameters/Number of Replicates--

A few critical performance, design, and cost parameters are investigated at the pilot-scale testing tier. These parameters are evaluated over a narrow range of values to optimize the technology's operation.

The pilot-scale testing tier often requires triplicate replication or more. A moderate to high level of QA/QC is generally needed to increase the confidence in the decision that the remedy selected can meet the performance goals for the site.

Study Size/Process Type/Waste Volume--

Pilot-scale testing typically involves pilot-plant or field-testing equipment with a configuration similar to that of the full-scale operating unit being considered. Pilot-scale testing may be conducted as either a batch or continuous process, depending on the operation of the full-scale unit. A substantial waste stream sample volume is required for pilot-scale testing. For example, the volume needed to perform continuous pilot-scale testing of an ion exchange treatment process for an aqueous waste may be on the order of 25 liters per minute for a run of 16 hours a day for a period of 3 weeks (which would require more than 500,000 liters of waste).

Time/Cost--

The duration and cost of pilot-scale testing depend primarily on the type of technology being investigated, the types of analyses being performed, and the number of replicates and length of runs required for adequate testing. Typically, pilot-scale tests can be performed within a time range of weeks to months at a cost of between $250,000 and $1,000,000. This cost estimate includes analytical support. The estimate of duration, however, is only for the actual performance of the test. It does not include the time required for mobilization, construction, shakedown, or demobilization of the pilot-scale unit, as these procedures are specific to the technology being investigated. Neither does it consider sample analysis or data validation, as these elements depend on the analytical laboratory used.

The increased cost of pilot-scale testing compared with that for laboratory screening or bench-scale testing is directly related to the larger scale of the technology, the more stringent QA/QC requirements, and the greater number of samples and replicates to be analyzed.

2.3 APPLYING THE TIERED APPROACH

The need for and tier of treatability testing required are risk-management decisions in which the costs and time required to conduct treatability studies are weighed against the risks inherent in the selection of a treatment alternative. As a general rule, treatability testing should continue until sufficient information has been collected to support both the full development and evaluation of all treatment alternatives and the remedial design of the selected alternative. Treatability studies can significantly reduce the overall risks and uncertainties associated with the selection and application of a technology, but they cannot guarantee that the chosen alternative will be completely successful. As more studies are completed and new knowledge is gained about innovative alternatives, however, success rates should improve.

The flow diagram for the tiered approach in Figure 3 traces the stepwise data reviews and management decisions that occur in the treatability study process.

After the site characterization and literature/data-base review, the RPM decides which technologies are potentially valid for the site and screens out those that are not. The decision to conduct a study is then based on the quantity and quality of available technology-specific information and on inputs from management. (Management decision factors are discussed in Subsection 2.3.1.)

If a treatability study is not required, the technology is retained for detailed analysis. If significant questions remain about the technology, a decision must be made regarding the nature of the information needed.

If the technology's validity has not been confirmed, a laboratory screening should be performed. If more quantitative performance data are required, the laboratory screening tier may be bypassed in favor of bench-scale testing.

If bench-scale testing indicates that the technology may meet the performance goals, the need for more data must be considered. Again, management inputs play a role in the decision as to whether to proceed with pilot-scale testing or to consider the technology investigation complete. In the latter case, the technology would be retained for future detailed analysis as a treatment alternative.

The detailed analysis of alternatives evaluates each technology against the nine evaluation criteria delineated in the RI/FS interim final guidance.

2.3.1 Management Decision Factors

The same factors that govern the decision to conduct treatability studies at a site also guide the tiered approach. The number of studies conducted and the tiers at which they occur are management decisions based on available data (from the literature and from previous treatability studies) and the following additional factors:

- State and community acceptance
- Responsible party considerations
- Schedule constraints
- Additional site or technology data

The RPM should weigh the technical and nontechnical factors to determine the need to progress to the next stage of treatability testing and should advise and involve management (e.g., Unit Chief) in this decision-making process.

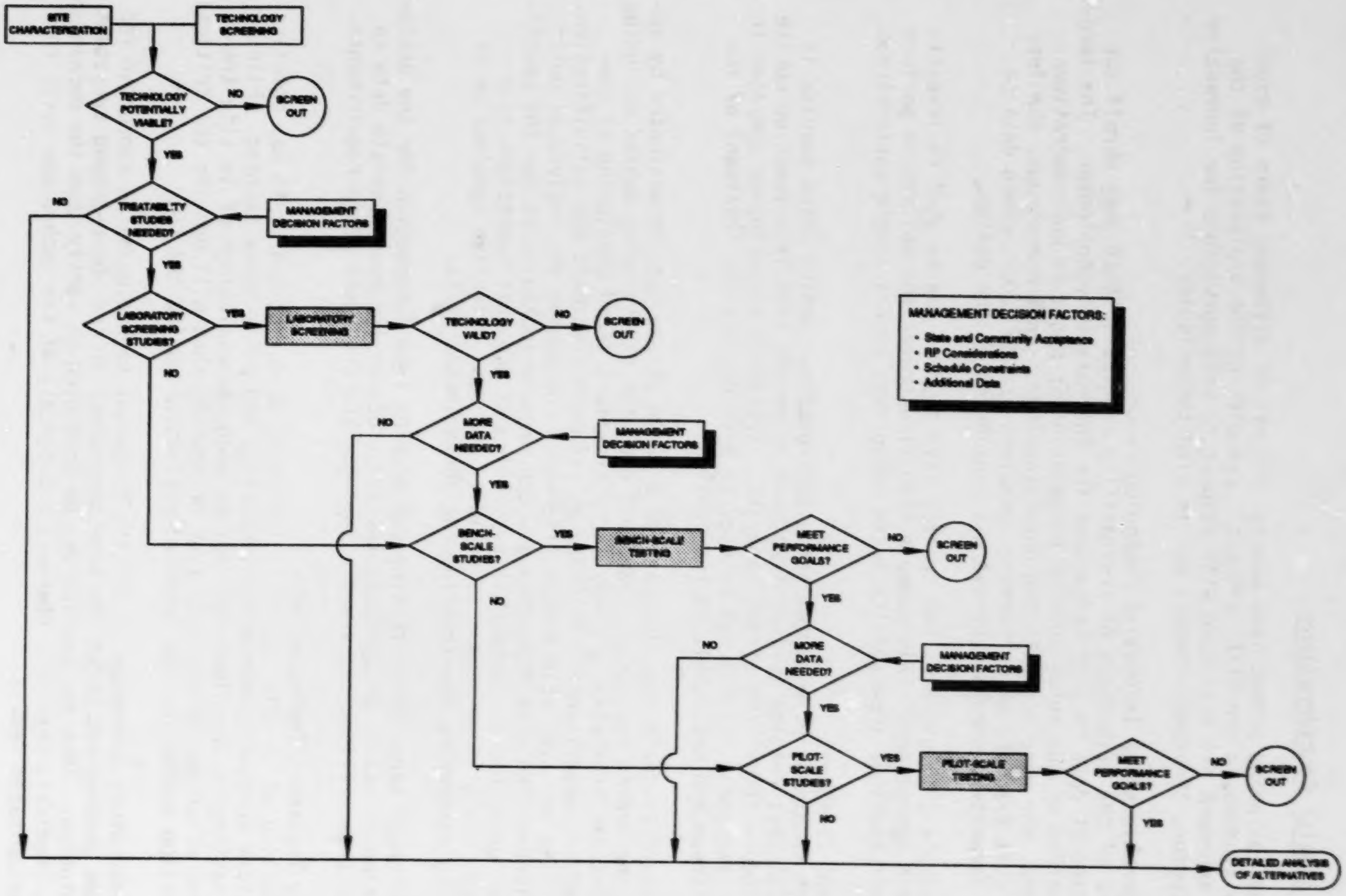

SITE CHARACTERIZATION
TECHNOLOGY SCREENING
TECHNOLOGY POTENTIALLY VIABLE?
NO
SCREEN OUT
YES
NO
TREATABILITY STUDIES NEEDED?
MANAGEMENT DECISION FACTORS
YES
LABORATORY SCREENING STUDIES?
YES
LABORATORY SCREENING
TECHNOLOGY VALID?
NO
SCREEN OUT
NO
YES
NO
MORE DATA NEEDED?
MANAGEMENT DECISION FACTORS
YES
BENCH-SCALE STUDIES?
YES
BENCH-SCALE TESTING
MEET PERFORMANCE GOALS?
NO
SCREEN OUT
NO
YES
NO
MORE DATA NEEDED?
MANAGEMENT DECISION FACTORS
YES
PILOT-SCALE STUDIES?
YES
PILOT-SCALE TESTING
MEET PERFORMANCE GOALS?
NO
SCREEN OUT
NO
YES
DETAILED ANALYSIS OF ALTERNATIVES
MANAGEMENT DECISION FACTORS:
• State and Community Acceptance
• RP Considerations
• Schedule Constraints
• Additional Data

Figure 3. Flow diagram of the tiered approach.

2.3.2 Special Considerations

The following subsections address the use of different tiers of treatability studies in the RI/FS process. Examples of the application of the tiered approach are developed with respect to unit operations for innovative technologies, treatment trains, and in situ technologies.

Unit Operations for Innovative Technologies--

One of the advantages of treatability studies is that they permit the collection of data on unit operations for innovative technologies. The largest fraction of the total cost of remediation is spent on unit operations; therefore, the more accurate the understanding of unit operations, the less likely cost overruns or performance problems are to occur. More data on design parameters expands the overall confidence in the design.

Example 2 illustrates how treatability studies can be used to investigate unit operations. This example also illustrates the ability to perform different tiers of treatability tests concurrently on a single waste stream.

Treatment Trains--

The treatment of a contaminated environmental medium often results in residuals that require further treatment to render them less toxic or mobile or to reduce the volume of the material. Treatment technologies operated in series (treatment trains) can be used to provide complete treatment of the waste stream and the resulting residuals.

Treatment-train requirements for a waste stream may be evaluated by applying the tiered approach. Example 3 explains the thinking behind designing a bench-scale treatability study for a treatment train consisting of low-temperature volatilization followed by chemical treatment and solidification. Enough data are available in the literature concerning the individual unit operations to indicate that they are appropriate technologies for the specific site contaminants. Treatability testing of the unit operations as a treatment train is necessary to evaluate the most effective combination of operating parameters for treating the contaminated soils.

Although bench-scale testing can provide some information for the design of treatment trains, pilot-scale testing produces the most accurate data on residuals generation, cross-media impacts, and treatment train requirements.

In Situ Treatment Technologies--

Testing of in situ treatment technologies during the RI/FS may entail laboratory screening, bench-scale testing, and pilot-scale testing. Pilot-scale testing is very important for an adequate evaluation of in situ treatment and often may be the only type of testing that will provide the critical information needed for the detailed evaluation during the FS.

Laboratory screening of in situ treatment technologies is conducted for the same purpose and under the same conditions as for above-ground treatment technologies. That is, testing may be conducted to verify that the mechanism (i.e., chemical, physical, thermal, biological) of the technology works on the contaminated matrix.

EXAMPLE 2. TREATABILITY STUDIES FOR UNIT OPERATIONS

OLD PETROLEUM REFINERY SITE

Background--

This example concerns an old petroleum refinery site containing oily sludges and contaminated soils. The primary contaminants of concern were polynuclear aromatic hydrocarbons (PAHs), specifically benzo(a)pyrene. The literature survey identified five potentially applicable technologies for treating the hydrocarbon wastes: 1) incineration, 2) low-temperature thermal treatment, 3) bioremediation, 4) stabilization/solidification, and 5) solvent extraction.

The literature survey also produced a significant amount of performance data for incineration and bioremediation. Because these performance data indicated that certain technologies could be valid for the types of wastes and contaminants of concern at the site, these technologies were not evaluated at the laboratory-screening level.

Conversely, little data were found on low-temperature thermal treatment, and the available performance data for solvent extraction and stabilization/solidification were inconclusive for hydrocarbon wastes. Therefore, these three technologies were evaluated at the laboratory screening level to determine their validity for the treatment of petroleum wastes.

Laboratory Screening--

In the case of low-temperature thermal treatment and solvent extraction, laboratory screening evaluated the percentage removal of oils/grease or total organic carbon in the wastes. In the case of stabilization/solidification, laboratory screening evaluated the percentage reduction of these materials. Samples of worst-case sludges (most highly contaminated with organics) and average-concentration samples were treated by each technology. A goal of 80 percent reduction was set, based on the established cleanup objectives. The data confidence levels required for the small data base was 90 percent.

Low-temperature thermal treatment was evaluated at three temperatures. Solvent extraction was evaluated by using three solvents at three solution concentrations. Stabilization/solidification was evaluated by using organophilic clays at three mix ratios. After the clays were cured, stabilized/solidified samples and untreated samples were evaluated by the toxicity characteristic leaching procedure (TCLP). The percentage reduction in leachate concentrations of oils/grease between the treated and untreated samples was determined, and the leachate levels of benzo(a)pyrene and the regulatory levels used to classify wastes were compared. Only the chemicals analyses (i.e., total organic carbon or oils/grease) were replicated.

The results of the laboratory screening showed that, of the three technologies, low-temperature thermal treatment achieved the highest level of percentage removal of total organic carbon (greater than 95 percent). Solvent extraction with the best solvent and highest concentration showed an 85 percent removal efficiency. Stabilization with the organophilic clays reduced leachate concentrations by 70 percent. Low-temperature thermal treatment and solvent extraction were thus retained for further analysis because they met the test performance goals.

Bench-Scale Testing--

Quantitative performance, implementability, and cost issues still remained unanswered after the laboratory screening tests. Also information from the literature on biodegration rates and mechanisms for benzo(a)pyrene (the principal contaminant of concern) was inconclusive. In addition, the cleanup goal for benzo(a)pyrene in soils was very low (250 ppb). Therefore, low-temperature thermal treatment, solvent extraction, and bioremediation were examined in bench-scale testing. Bench-scale performance goals were set at 98 percent reduction with 95 percent data confidence level. Samples representing average and worst-case scenarios were collected, triplicate analyses were performed, and several process variables were evaluated. After 6 months of testing, only low-temperature thermal treatment was found to meet the low cleanup levels required for benzo(a)pyrene.

Decision Based on Laboratory Screening and Bench-Scale Testing--

Although low-temperature thermal treatment was found to meet the cleanup requirements in bench-scale testing, this technology had not been previously demonstrated on a pilot scale. Therefore, cost and design issues had to be addressed as part of the detailed analysis of alternatives. In addition, whereas utility costs for low-temperature thermal treatment would be less than those for incineration, the costs of constructing and operating the low-temperature thermal unit could be significantly higher than those that would be incurred for incineration because the former is an innovative technology. Therefore, the RPM decided to conduct pilot-scale testing on low-temperature thermal treatment and to compare the costs of constructing and operating the unit with those for incineration. The results would be used to select the optimal treatment alternative (i.e., incineration or low-temperature thermal treatment) for the wastes at the site.

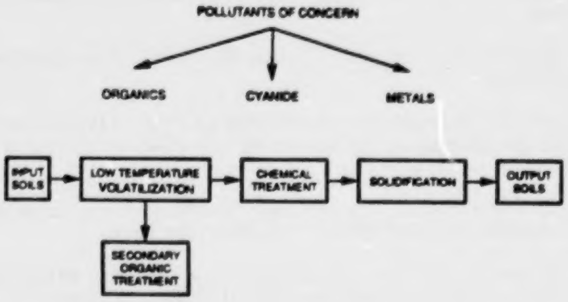
EXAMPLE 3. TREATABILITY STUDIES FOR TREATMENT TRAINS

FORMER CHEMICAL MANFUACTURING COMPANY

Background--

At a former chemical manufacturing company and current Superfund site in Virginia, the contaminants of concern in the soils are arsenic, cyanide, methylene chloride, benzene, tetrachloroethene, and total polynuclear aromatic hydrocarbons (PAHs). The cleanup goal for each of these compounds has been identified. Both onsite treatment and offsite treatment and disposal are being considered as viable options for site remediation; therefore, analyses of the total organics and inorganics composition must be performed on the treated and untreated soils to determine if target soil concentrations have been achieved. At the same time, TCLP analyses must be performed to determine pollutant-of-concern concentrations that can be extracted from the treated and untreated soils.

Bench-scale testing of a treatment train that can be used to treat the contaminated soils was designed to include the following unit operations: 1) low-temperature volatilization, 2) chemical treatment, and 3) solidification. A schematic of the treatment train is presented below.



Schematic Representation of the Treatment Train

Bench-Scale Testing--

The bench-scale testing of the treatment train was designed to meet the following five objectives:

- Objective 1 - Provide performance confirmation of the low-temperature volatilization unit operation and pollutant-of-concern concentration data to determine if chemical treatment and solidification units are necessary.
- Objective 2 - Provide performance confirmation of the chemical treatment unit operation and pollutant-of-concern concentration data to determine if the solidification unit is necessary.
- Objective 3 - Verify effectiveness of the proposed treatment train for achieving the target soil concentrations. [Associated pollution-control devices (e.g., fume incineration) are assumed to be off-the-shelf items and are not addressed as part of this bench-scale work.]

- Objective 4 - Address the use of hydrogen peroxide or hypochlorite for cyanide treatment with respect to the following items:
  - The potential for uncontrolled reactions
  - Process effectiveness as a function of pH, strength of solution, ratio of amount of solution to soil to be treated
  - The effects of additives (metal scavenging on chemical treatment products and byproducts)
  - The need to degas treated soil
  - The need for solidification after treatment and the effects of the treatment agent and associated gases and other products on solidification
  - The effects on organic constituents
  - The effect of soil temperature on subsequent chemical treatment
  - The effect of varying degrees of thermal treatment on the process
- Objective 5 - Address the effectiveness of solidification as a stand-alone technology to determine the effectivenesss of the solidification unit.

The bench-scale testing of the proposed treatment train consisted of the following four subtasks, each of which is summarized here.

a. Execute bench-scale testing to determine the most effective binder/soil combination for treating the pollutants of concern.

   - Select one of three laboratory-standard generic binders (portland cement Type I; cement kiln dust; or a mixture of lime and Type F fly ash) and a second binder containing silicates.
   - Test both binders at three binder to soil ratios (on a dry weight basis), varying from 0.1 to 0.6 (binder to soil) for a total of six trial mixes.
   - Analyze treated soils for physical characteristics (e.g., grain size, moisture content, specific gravity), inorganic composition analysis (arsenic and cyanide), organic composition analysis (methylene chloride, benzene, tetrachloroethene, total PAHs), unconfined compressive strength, toxicity characteristic leaching procedure (TCLP) (for all target compounds), SW-846 Method 1320 (for all target compounds), wet/dry weight, permeability, bulk specific gravity, volumetric bulking, acid neutralization capacity, and American Nuclear Society (ANS) leach test.

   This subtask addresses Objective 5 and part of Objective 3.

b. Execute a low-temperature volatilization/solidification test by using a high temperature (550°F) and a long residence time (e.g., 40 minutes) to determine the efficacy of the low-temperature volatilization unit. Perform solidification tests on the treated soil to determine which combination of low-temperature volatilization and solidification is most effective in treating the pollutants of concern.

Analyze treated soils for physical characteristics (e.g., grain size, moisture content, specific gravity), inorganic composition analysis (arsenic and cyanide), organic composition analysis (methylene chloride, benzene, tetrachloroethene, total PAHs), unconfined compressive strength, TCLP (for all target compounds), SW-846 Method 1320 (for all target compounds), wet/dry weight, permeability, bulk specific gravity, volumetric bulking, acid neutralization capacity, and ANS leach test.

This subtask addresses Objective 1 and part of Objective 3.

c. Execute bench-scale testing of low-temperature volatilization/chemical treatment/solidification using a high pH (e.g., 10), long residence time (e.g., 2 hours), and high oxidant-to-cyanide ratio (e.g., 3:1) to determine the efficacy of the low-temperature volatilization/chemical treatment unit. Test either hydrogen peroxide or hypochlorite.

Perform solidification tests on the treated soil to determine which combination of low-temperature volatilization, chemical treatment, and solidification is most effective in treating the pollutants of concern.

Analyze treated soils for physical characteristics (e.g., grain size, moisture content, specific gravity), inorganic composition analysis (arsenic and cyanide), organic composition analysis (methylene chloride, benzene, tetrachloroethene, total PAHs), unconfined compressive strength, TCLP (for all target compounds), SW-846 Method 1320 (for all target compounds), wet/dry weight, permeability, bulk specific gravity, volumetric bulking, acid neutralization capacity, and ANS leach test.

This subtask addresses portions of Objective 4, Objective 2, and the remainder of Objective 3.

d. Prepare a summary and analysis of preliminary findings of the bench-scale testing to be used to assess whether the objectives of the study have been met, if further bench-scale study needs to be done, or if pilot-scale testing is required to provide the needed data for remedy selection.

Bench-scale testing of the efficacy of using in situ technologies for treating contaminated soils would likely be conducted in soil columns designed to represent the subsurface environment. A column diameter of approximately 4 inches is usually suitable for simulating hydraulic flow conditions in the subsurface.

Pilot-scale testing in the field may be required more often for evaluating in situ treatment technologies than for evaluating above-ground treatment technologies. Monitoring treatment effectiveness is a major concern in pilot-scale testing and must be considered during design and costing efforts.

Example 4 demonstrates how the tiered approach is used to evaluate the technology of soil flushing. Soil flushing is an extraction process in which contaminants are "flushed" from the soil by an aqueous solution (e.g., water, a surfactant, a chelating agent, or an organic solvent), collected in a drainage system (e.g., wells or a leachate collection system), pumped to the surface, treated, and recycled back through the soil for further flushing.

EXAMPLE 4. TREATABILITY STUDIES FOR IN SITU TREATMENT TECHNOLOGIES

IN SITU SOIL FLUSHING

Background--

An estimated 80,000 cubic yards of soil contaminated with chlorinated phenols, semivolatile organics, sulfur-containing compounds, and lead required corrective action. In situ soil flushing was proposed as the alternative treatment technology. A three-tiered treatability study was designed to evaluate the effectiveness of this technology.

Laboratory Screening--

Batch laboratory screening can be performed to evaluate the effectiveness of flushing fluids for enhancing the removal of the site-specific contaminants. The general procedure is as follows:

- Place a known weight of soil in a 250-ml glass bottle, add a measured volume of flushing fluid, and shake for 1 to 4 hours.
- Centrifuge the bottle and recover the supernatant liquid phase. Analyze for target compounds.
- Analyze the soil phase for site-specific target compounds.
- Evaluate several different flushing media to determine the removal efficiencies for each of the site-specific contaminants.

During the soil flushing evaluation phase, analyzing all samples for all the site-specific contaminants may not be economically feasible; therefore, target compounds, each representative of a class of compounds present at the site, should be analyzed.

Bench-Scale Testing--

Upon completion of the batch laboratory screening, the flushing solutions shown to be the most effective for removal of target contaminants should be evaluated in a column test. A general procedure for the soil flushing column test is as follows:

- Pack a glass column with soil from the contaminated area to approximate the actual density of soil in the area. The initial concentration of contaminants should be determined before the soil is packed in the columns.
- Introduce the soil flushing solution into the column and allow it to percolate through the column. Collect the column leachate at regular intervals (e.g., weekly) and analyze for target compounds.
- Collect the leachate generated in the soil column and use it for additional bench-scale testing evaluations involving treatment of the leachate.
- Terminate the column test when the composition of the leachate remains the same for three consecutive sampling periods. At the conclusion of the column flushing test, remove samples of the soil from the column and analyze them for the target parameters.

The goal of this study is to verify performance of the most environmentally compatible flushing fluid that will solubilize and remove target contaminants.

Pilot-Scale Testing--

Pilot-scale testing of this technology should occur in the field. The purpose of the field demonstration is to evaluate the hydraulics of the treatment process under site conditions. The field demonstration will yield site-specific flow, injection, and capture rates for the flushing system. These rates must be established for quantification of the total time necessary for final soil treatment and to provide data for remedy design and cost. The pilot-scale testing involves the following tasks:

- Prepare treatment cell site
- Install interception trench
- Install irrigation and soil flushing system
- Monitor performance
- Operation and maintenance
- Test possible leachate treatment systems

SECTION 3

PROTOCOL FOR CONDUCTING TREATABILITY STUDIES

3.1 INTRODUCTION

Treatability studies should be performed in a systematic fashion to ensure that the data generated can support the remedy evaluation process. This section describes a general approach or protocol that should be followed by RPMs, RPs, and contractors for all phases of the investigation. This approach includes:

- Establishing data quality objectives
- Selecting a contracting mechanism
- Issuing the Work Assignment
- Preparing the Work Plan
- Preparing the Sampling and Analysis Plan
- Preparing the Health and Safety Plan
- Conducting community relations activities
- Complying with regulatory requirements
- Executing the study
- Analyzing and interpreting the data
- Reporting the results

These elements are described in detail in the remaining subsections of Section 3. General information applicable to all treatability studies is presented first, followed by information specific to laboratory screening, bench-scale testing, and pilot-scale testing.

Treatability studies for a particular site will often entail multiple tiers of testing, as described in Subsection 2.3. Duplication of effort can be avoided by recognition of this possibility in the early planning phases of the project. The Work Assignment, Work Plan, and other supporting documents should include all anticipated activities, and a single contractor should be retained to ensure continuity in the project as it moves from one tier to another.

3.2 ESTABLISHING DATA QUALITY OBJECTIVES

The establishment of data quality objectives (DQOs) is part of the process that defines the data quality needs of a project. The implementation of an appropriate quality assurance/quality control (QA/QC) program is required to ensure that data of known and documented quality are generated. The DQOs may be qualitative or quantitative in nature, but in either case, they must be specified prior to data collection. Because treatability testing is used to decide whether a particular remedial alternative is valid and/or effective, establishing DQOs is a critical early step in the planning and conducting of treatability tests, as discussed in Subsection 2.1.3.

The quality of treatability testing data required should correspond proportionately with the implications of the decisions that will be based on those data. Generally, limited QA/QC is required for data from simple laboratory screening tests used to decide whether a treatment process is potentially applicable and warrants further consideration. More rigorous QA/QC is required for bench-scale and pilot-scale testing data used to determine whether a technology can meet the expected cleanup criteria or to compare the costs of several treatment alternatives because the decisions have more far-reaching implications.

3.2.1 General

The guidance document Data Quality Objectives for Remedial Response Activities (EPA 1987a) defines the framework and process by which the DQOs are developed. This document focuses on site investigations during an RI/FS; however, the same framework and process are applicable to treatability studies. The document describes a three-stage process: Stage 1 involves identification of decision types; Stage 2 entails the identification of data uses/needs; and Stage 3 covers the design of the data-collection program.

In Stage 1, determining the types and magnitudes of decisions to be made entails identifying and involving the data users in establishing the DQOs, evaluating existing data, and specifying the objective(s) of the treatability study. For example, is the objective of the study to test the validity of the technology (i.e., does it warrant further consideration) or must the study confirm the attainment of a treatment standard? As the consequences of making a wrong decision increase, so must the data quality and quantity.

During Stage 2, criteria for determining data adequacy are stipulated or the data necessary to meet the objectives of Stage 1 are specified. Stage 2 also includes selection of sampling approaches and analytical options.

During Stage 3, methods for obtaining data of acceptable quality and quantity are chosen and incorporated into the project Work Plan, the Sampling and Analysis Plan, and the Quality Assurance Project Plan.

Data quality considerations for treatability testing must consider both sampling and analytical efforts. Whereas most measurements of data quality address analytical techniques, they must also factor in the test design and sampling events.

The EPA's DQO guidance establishes five analytical levels for use in the RI/FS process. These analytical levels are summarized in Table 2.

TABLE 2. SUMMARY OF ANALYTICAL LEVELS[a]

Level I	
Type of analysis	Field screening or analysis with portable instruments.
Limitations	Usually not compound-specific, but results are available in real time. Not quantifiable.
Data quality	Can provide an indication of contamination presence. Few QA/QC requirements.
Level II	
Type of analysis	Field analyses with more sophisticated portable instruments or mobile laboratory. Organics by GC, inorganics by AA, ICP, or XRF.
Limitations	Detection limits vary from low parts per million to low parts per billion. Tentative identification of compounds. Techniques/instruments limited mostly to volatile organics and metals.
Data quality	Depends on QA/QC steps employed. Data typically reported in concentration ranges.
Level III	
Type of analysis	Organics/inorganics performed in an offsite analytical laboratory. May or may not use CLP procedures. Laboratory may or may not be a CLP laboratory.
Limitations	Tentative compound identification in some cases.
Data quality	Detection limits similar to CLP. Rigorous QA/QC.
Level IV	
Type of analysis	Hazardous Substances List (HSL) organics/inorganics by GC/MS, AA, ICP. Low parts-per-billion detection limits.
Limitations	Tentative identification of non-HSL parameters. Validation of laboratory results may take several weeks.
Data quality	Goal is data of known quality. Rigorous QA/QC.
Level V	
Type of analysis	Analysis by nonstandard methods.
Limitations	May require method development or modification. Method-specific detection limits. Will probably require special lead time.
Data quality	Method-specific.

[a] Source: EPA 1987a (modified).

In general, analytical levels I and II apply to laboratory screening treatability studies, and analytical levels III, IV, and V apply to bench- and pilot-scale treatability studies.

Once the data quality needs for a project have been defined, confidence limits can be established for the data to be generated. In general, the higher the data quality needs, the narrower the confidence interval must be (e.g., the required confidence limits for data of high quality may be ±5 percent, whereas confidence limits of ±25 percent may be sufficient for data of lower quality).

Specific confidence limits have not been established for each treatability study tier. Rather, the intended use of the data and the limitations and costs of various analytical methods will assist the RPM in defining appropriate confidence limits for the tier of testing being planned.

Data quality needs also affect the QA/QC requirements and documentation. As data quality needs increase, a greater number of QC checks (such as spikes and blanks) must be used. Also, a more detailed quality assurance plan must be prepared to document the quality of the data.

3.2.2 Laboratory Screening

Laboratory screening is performed to determine the potential applicability of emerging or innovative technologies. Laboratory screening is also applied when performance data for a well-developed technology are inconclusive or questionable with respect to specific waste characteristics. For example, whereas soil washing has been well demonstrated on sandy soils, performance data for loamy or silty soils may be inconclusive or nonexistent. Also, where solidification/stabilization is known to be effective for treating metal-containing wastes, its effectiveness with respect to organic contaminants is still questionable and should be verified through laboratory screening.

The DQOs established for laboratory screening are usually stated in qualitative terms. Laboratory screening evaluates primary waste variables such as percent solids, total organic carbon, or pH. Therefore, analytical levels I and II usually provide sufficient information for laboratory screening. Because laboratory screening does not directly support the remedy selection, it does not require a significant amount of replication in the samples and the analytical tests performed.

Confidence limits established for data derived from laboratory screening are typically wide, in keeping with the characteristics of this level of study (i.e., low cost, quick turnaround, and limited QA/QC).

3.2.3 Bench-Scale Testing

For bench-scale testing, DQOs are primarily quantitative in nature. For example, an objective for bench-scale testing involving solvent extraction and chemical dechlorination may be to reduce polychlorinated biphenyls (PCBs) to less than 30 ppm in soils (the target cleanup goal specified for the site), whereas an objective for testing involving stabilization/solidification of the residuals from soil washing may be to pass the toxicity characteristic leaching procedure (TCLP) leachate levels required for disposal of the residuals. Other objectives may be to evaluate volume increase (in the case of stabilization/solidification) or to determine the fines content of the residuals from soil washing. Therefore, objectives for bench-scale testing will result in more quantitative evaluations of the critical engineering parameters affecting design, performance, and costs. Analytical levels III through V are usually specified for bench-scale testing activities.

The data required to meet these quantitative objectives include more detailed waste characterization and performance testing with narrower confidence limits, depending on the RPM's intended use of the data. Data used as the sole support of a remedy selection should have a high level of confidence.

Because the principal objective is to quantify the performance and cost of a technology, the parameters to be studied will include those that effectively characterize the types of wastes to be treated and the critical engineering parameters. In the case of stabilization/solidification, the critical waste characterization parameters may be particle size, moisture content, pH, total organic carbon, sulfides content, and concentrations of the indicator compounds. The critical engineering parameters evaluated may be the type of stabilizer (lime, cement, organophillic clays) and the mix ratios. The critical performance test may be leaching (using TCLP), strength of the solidified matrix (based on unconfined compressive strength), percentage of volume increase of the solidified product, and biotoxicity of the treated product.

Because of the more detailed analyses, the narrower confidence limits, and the resulting need for a higher level of QA/QC, the sample size will be much larger than required for laboratory screening. Chemical analyses also may be more thorough (e.g., a scan for priority pollutants rather than analyzing only for oils/grease).

3.2.4 Pilot-Scale Testing

The principal objective of pilot-scale testing is to obtain quantitative performance, design, and cost data to be used in the feasibility study or in the implementation of the remedial technology. Therefore, DQOs are primarily quantitative in nature and related to process optimization.

For example, an objective for pilot-scale testing involving bioremediation of ground water may be to reduce benzene and phenol concentrations to safe drinking water levels. Other objectives for bioremediation pilot-scale testing may be to quantify optimum critical process parameters, such as pH, nutrient addition, and oxygen requirements for the unit operation. Therefore, quantitative objectives for pilot-scale testing will result in more quantitative evaluations of critical engineering parameters affecting the design, performance, and cost of the remedial alternative.

Because the principal objective is to quantify the performance and cost of a technology, the number of parameters to be studied may be limited to those that effectively characterize the types of waste to be treated and the critical engineering parameters that affect the cost and performance of a technology. As with bench-scale testing, analytical levels III through V are appropriate for pilot-scale testing. In the case of bioremediation pilot-scale testing, the critical waste characterization parameters may be particle size, moisture content, total metals, total organic carbon, nutrient content, and concentration of indicator compounds. The critical process parameters to be evaluated may be reactor residence time, effective temperatures, water distribution, and nutrient additives. The performance tests may be chemical analyses for indicator compounds, leach tests, and biotoxicity of the treated product.

The need for design, cost, and performance information will dictate the frequency of sampling and testing, the required confidence limits, and the level of QA/QC. In general, pilot-scale testing will involve daily or weekly sampling and significant replication in sampling and analyses. Chemical analyses may include more costly and thorough analytical methods (e.g., GC/MS for organics) as well as gross indicator analytes (e.g., pH, total organic carbon, total metals, oxygen content).

3.3 SELECTING A CONTRACTING MECHANISM

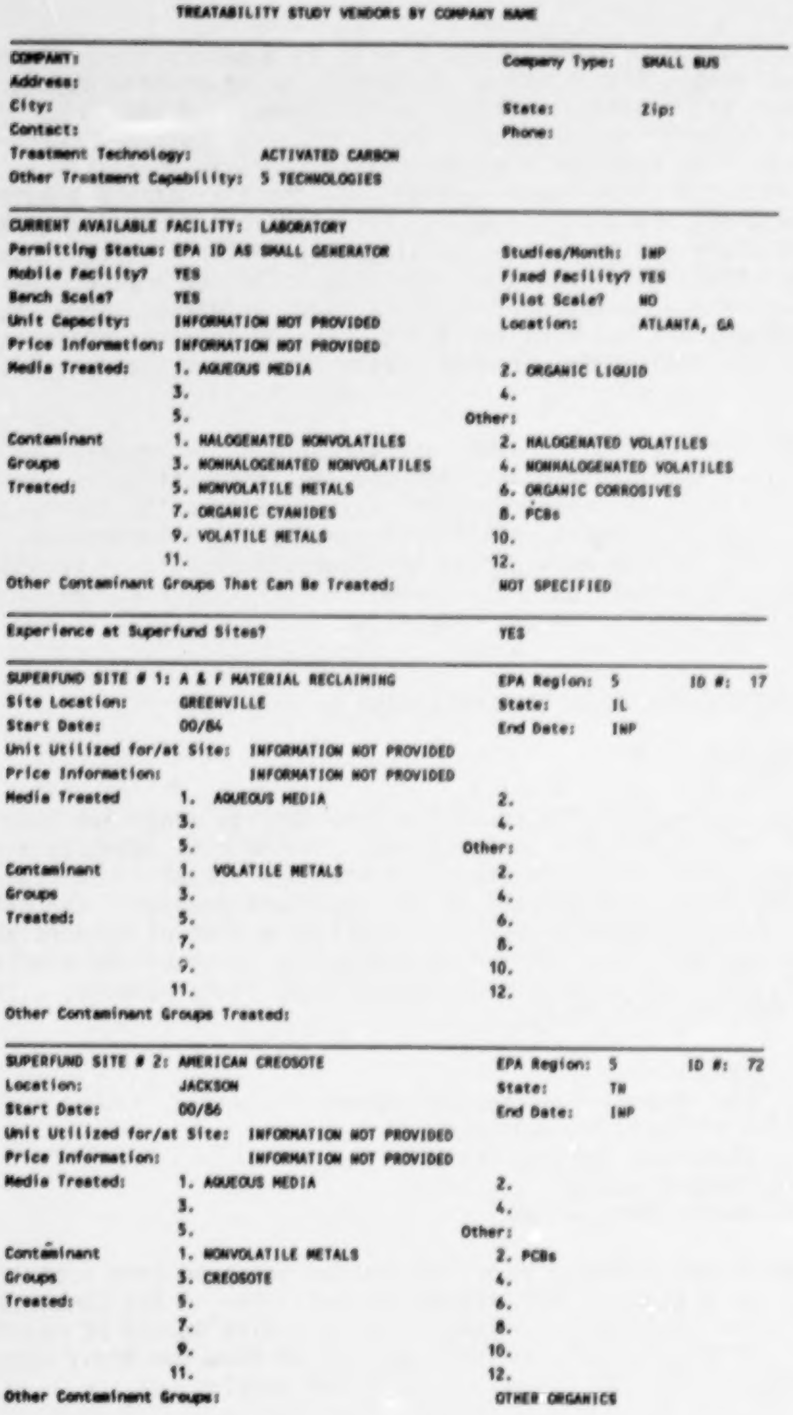
3.3.1 General

Once the decision to conduct a treatability study has been made and the scope of the project has been defined, the RPM must identify a contractor or technology vendor with the requisite technical capabilities and experience to perform the work. In support of the Superfund programs, the Office of Research and Development (ORD) has compiled a list of vendors and contractors who have expressed an interest in performing treatability studies. This document, entitled Inventory of Treatability Study Vendors, will be be available in 1990 by contacting:

Ms. Joan Colson
U.S. Environmental Protection Agency
Office of Research and Development
Risk Reduction Engineering Laboratory
26 W. Martin Luther King Drive
Cincinnati, Ohio 45268

The document was compiled from information received from contractor/vendor responses to a request for information published in the Commerce Business Daily (August 31, 1989). Companies on this list should be notified of a request for proposal (RFP) for treatability studies for their area of expertise in accordance with the Federal Acquisition Regulations.

The inventory is sorted by treatment technology, contaminant group, and company name. Figure 4 shows the type of information contained in the inventory. Plans call for this inventory to be incorporated into one of the technical information services maintained by ORD.



```
                  TREATABILITY STUDY VENDORS BY COMPANY NAME
______________________________________________________________________________
COMPANY:                                          Company Type:   SMALL BUS
Address:
City:                                             State:          Zip:
Contact:                                          Phone:
Treatment Technology:       ACTIVATED CARBON
Other Treatment Capability: 5 TECHNOLOGIES
______________________________________________________________________________
CURRENT AVAILABLE FACILITY:  LABORATORY
Permitting Status: EPA ID AS SMALL GENERATOR      Studies/Month:  INP
Mobile Facility?   YES                            Fixed Facility? YES
Bench Scale?       YES                            Pilot Scale?    NO
Unit Capacity:     INFORMATION NOT PROVIDED       Location:       ATLANTA, GA
Price Information: INFORMATION NOT PROVIDED
Media Treated:     1. AQUEOUS MEDIA               2. ORGANIC LIQUID
                   3.                             4.
                   5.                          Other:
Contaminant        1. HALOGENATED NONVOLATILES    2. HALOGENATED VOLATILES
Groups             3. NONHALOGENATED NONVOLATILES 4. NONHALOGENATED VOLATILES
Treated:           5. NONVOLATILE METALS          6. ORGANIC CORROSIVES
                   7. ORGANIC CYANIDES            8. PCBs
                   9. VOLATILE METALS            10.
                  11.                            12.
Other Contaminant Groups That Can Be Treated:     NOT SPECIFIED
______________________________________________________________________________
Experience at Superfund Sites?                    YES
______________________________________________________________________________
SUPERFUND SITE # 1: A & F MATERIAL RECLAIMING     EPA Region:  5      ID #:  17
Site Location:      GREENVILLE                    State:       IL
Start Date:         00/84                         End Date:    INP
Unit Utilized for/at Site:  INFORMATION NOT PROVIDED
Price Information:          INFORMATION NOT PROVIDED
Media Treated       1.  AQUEOUS MEDIA              2.
                    3.                             4.
                    5.                          Other:
Contaminant         1.  VOLATILE METALS            2.
Groups              3.                             4.
Treated:            5.                             6.
                    7.                             8.
                    9.                            10.
                   11.                            12.
Other Contaminant Groups Treated:
______________________________________________________________________________
SUPERFUND SITE # 2: AMERICAN CREOSOTE             EPA Region:  5      ID #:  72
Location:           JACKSON                       State:       TN
Start Date:         00/86                         End Date:    INP
Unit Utilized for/at Site:  INFORMATION NOT PROVIDED
Price Information:          INFORMATION NOT PROVIDED
Media Treated:      1. AQUEOUS MEDIA               2.
                    3.                             4.
                    5.                          Other:
Contaminant         1. NONVOLATILE METALS          2. PCBs
Groups              3. CREOSOTE                    4.
Treated:            5.                             6.
                    7.                             8.
                    9.                            10.
                   11.                            12.
Other Contaminant Groups:                         OTHER ORGANICS
```

Figure 4. Information contained in EPA's inventory of treatability study vendors.

Three methods of obtaining treatability study services from contractors are discussed in the subsections that follow.

REM or ARCS Contracts--

Remedial Engineering Management (REM) and Alternative Remedial Contracts Strategy (ARCS) contracts are used to obtain program management and technical services needed to support remedial response activities at CERCLA sites. To retain a treatability study vendor through this mechanism, the RPM (in conjunction with the EPA contract officer for the particular contract) must issue a Work Assignment to the prime contractor outlining the required tasks. The prime contractor may elect to retain this work for itself or may choose to assign the work to one of its subcontractors.

Technical Assistance and Support Contracts--

In situations where the RPM knows that a specific waste at a specific site requires the specialized services of a contractor capable of treating that waste (e.g., a mixed radioactive/hazardous waste) and these required services are not available from firms accessible through existing REM or ARCS contracts, the RPM may need to investigate which firms having this specialized capability may be accessible through other contracting mechanisms. Limited access to technical assistance and support contracts may be available through ORD's Risk Reduction Engineering Laboratory (RREL), the U.S. Bureau of Mines (BOM), or the U.S. Army Corps of Engineers.

Request for Proposal--

In the absence of an existing contracting mechanism with which to access the required treatability study services for a specific waste at a particular site, the required services may be obtained through a new contracting mechanism. Obtaining the services of a specific firm through a new contracting mechanism, which can be a time-consuming process, typically involves three steps: 1) request for proposal (RFP), 2) bid review and evaluation, and 3) contract award.

An RFP is an invitation to firms to submit proposals to conduct specific services. It usually contains the following key sections:

- The type of contract to be awarded (e.g., fixed-price or cost plus fixed fee)
- Period of performance
- Level of effort
- Type of personnel (levels and skills)
- Project background
- Scope of work
- Technical evaluation criteria
- Instructions for bidders (e.g., due date, format, assumptions for cost proposals, page limit, number of copies)

All appropriate firms listed in the Inventory of Treatability Study Vendors should be notified of the RFP. Proposals submitted by a fixed due date in response to an RFP go to several reviewers to determine the prospective firms' abilities to conduct the required services. The technical proposals should be evaluated (scored) by using a standard rating system, which is based on the technical evaluation criteria presented in the RFP. Contract award should be based on a firm's ability to meet the technical requirements of the testing involved, its qualifications and experience in conducting similar studies, the availability and adequacy of its personnel and equipment resources, and (other things being equal) a comparison of cost estimates.

During the performance of treatability studies, a close working relationship should be established with the selected treatability study vendor. The vendor conducting the treatability study should be monitored for responsiveness, quality of documentation, and cost control.

3.3.2 Laboratory Screening

Laboratory screening involves relatively simple tests with no special equipment requirements. These studies generally can be performed by the prime REM or ARCS contractor or by the State or RP prime support services contractor.

3.3.3 Bench-Scale Testing

Bench-scale testing of proven or demonstrated technologies can sometimes be performed by the REM or ARCS contractor. Tests involving innovative technologies, however, may require special capabilities that are only accessible through technical assistance and support contracts or an RFP. Firms offering such capabilities can be identified through the Inventory of Treatability Study Vendors.

3.3.4 Pilot-Scale Testing

Pilot-scale testing involves more complex tests, with specialized equipment requirements. Such capabilities may not be available through any existing contracting mechanism within the Agency; therefore, it may be necessary to issue an RFP. Firms with the requisite pilot-scale testing capabilities can be identified through the Inventory of Treatability Study Vendors.

3.4 ISSUING THE WORK ASSIGNMENT

3.4.1 General

The Work Assignment is a contractual document that outlines the scope of work to be provided by the contractor. It gives the rationale for conducting the study, identifies the waste stream and technology(ies) to be tested, and specifies the level(s) of testing required (i.e., laboratory screening, bench-scale testing, and/or pilot-scale testing). Table 3 presents the suggested organization of the treatability study Work Assignment.

Background--

The background describes the site, the waste stream, and the remedial technology under investigation. Site-specific concerns that may affect waste handling, the experimental design, or data interpretation, as well as specific process options of interest, should be duly noted. The results of any previous treatability studies conducted at the site also should be included.

TABLE 3. SUGGESTED ORGANIZATION OF TREATABILITY STUDY WORK ASSIGNMENT

1. Background
    - 1.1 Site description
    - 1.2 Waste stream description
    - 1.3 Remedial technology description
    - 1.4 Previous treatability studies at the site
2. Test Objectives
3. Approach
    - 3.1 Task 1 - Work Plan preparation
    - 3.2 Task 2 - SAP, HSP, and CRP preparation
    - 3.3 Task 3 - Treatability study execution
    - 3.4 Task 4 - Data analysis and interpretation
    - 3.5 Task 5 - Report preparation
    - 3.6 Task 6 - Residuals management
4. Reporting Requirements
    - 4.1 Deliverables
    - 4.2 Monthly reports
5. Schedule
6. Level of Effort

Test Objectives--

This section defines the objectives of the treatability study and the intended use of the data (i.e., to validate a technology, to evaluate performance, or to provide cost or design data). The test objectives, which may differ for the three treatability study tiers, should be based on established cleanup goals for the site or, when such goals do not exist, on levels that are protective of human health and the environment. If the treatability study Work Assignment is issued before site cleanup goals have been established, the test objectives should be written with enough latitude to accommodate changes as treatability testing proceeds without modifying the Work Assignment.

Approach--

The approach describes the manner in which the treatability study is to be conducted. This discussion should address the following six tasks:

Task 1 - Work Plan preparation
Task 2 - SAP, HSP, and CRP preparation
Task 3 - Treatability study execution
Task 4 - Data analysis and interpretation
Task 5 - Report preparation
Task 6 - Residuals management

Task 1 - Work Plan preparation--This task outlines the elements to be included in the Work Plan. If a project kick-off meeting is needed to define the goals of the treatability study or to review the experimental design, it should be specified here. The contractor will begin work on subsequent tasks only after receiving approval of the Work Plan by the RPM.

Task 2 - SAP, HSP, and CRP preparation--This task describes activities specifically related to the treatability study that should be incorporated into the existing site Sampling and Analysis Plan (SAP), Health and Safety Plan, (HSP) and Community Relations Plan (CRP). Examples of such activities include field sampling and waste stream characterization, operation of pilot-plant equipment, and public meetings to discuss treatability study findings.

Task 3 - Treatability study execution--Requirements for executing the treatability study are outlined in this task. It should require that the contractor review the literature and site-specific information, identify key parameters for investigation, and specify conditions of the test. This task also should identify guidance documents (such as this guide or other technology-specific protocols) that should be consulted during the planning and execution of the study.

Task 4 - Data analysis and interpretation--This task describes how data from the treatability study will be used in the evaluation of the remedy. If statistical analysis of the data is required, the requirements should be set forth here.

Task 5 - Report preparation--This task describes the contents and organization of the final project report. If multiple tiers of testing are expected, an interim report may be requested at the completion of each tier. This task should require the contractor to follow the reporting format outlined in Subsection 3.12.

Task 6 - Residuals management--Residuals generated as a result of treatability testing must be managed in an environmentally sound manner. This task should specify whether project residuals are to be returned to the site or shipped to an acceptable offsite facility. In the latter case, this task also should identify the waste generator (lead agency, responsible party, or contractor).

Reporting Requirements--

This section identifies the project deliverables and monthly reporting requirements. Project deliverables include the Work Plan; the SAP, HSP, and CRP (as appropriate); and interim and final reports. Format specifications and the number of copies to be delivered should be stated. The Work Assignment must include a requirement for one camera-ready master copy of the treatability study report to be provided to the Office of Research and Development for use in updating the Superfund Treatability Data Base (EPA 1989b). The report should be sent to the following address:

Mr. Kenneth A. Dostal
Superfund Treatability Data Base
U.S. Environmental Protection Agency
Office of Research and Development
Risk Reduction Engineering Laboratory
26 W. Martin Luther King Drive
Cincinnati, Ohio 45268

Monthly reports should summarize progress for the current month, projected progress for the coming month, any problems encountered, and expected versus actual costs incurred. They should be submitted no later than the 10th day of the month following the reporting period.

Schedule--

The schedule establishes the timeframe for conducting the treatability study and includes due dates for submission of the major project deliverables. Sufficient time should be allowed for Work Plan, subcontractor, and other administrative approvals; site access and sampling; analytical turnaround; and review and comment on reports.

Level of Effort--

The level of effort estimates the number of technical hours necessary to complete the project. If special skills or expertise are required, they should be noted here.

3.4.2 Laboratory Screening

The purpose of laboratory screening is to establish the validity of a technology for treatment of wastes at the site and to focus resources in subsequent bench- or pilot-scale testing. The Work Assignment should describe how the results of laboratory screening will be used to determine if further testing at the bench or pilot scale is warranted.

3.4.3 Bench-Scale Testing

The purpose of bench-scale testing is to evaluate the performance of a technology and to obtain preliminary cost and design information. The objectives of bench-scale testing should be clearly stated. If laboratory screening will not be conducted, the Work Assignment should identify the critical parameters to be investigated.

3.4.4 Pilot-Scale Testing

The purpose of pilot-scale testing is to evaluate the performance of a technology and to obtain detailed cost and design information. Like bench-scale testing, the objectives of pilot-scale testing should be clearly stated. In addition to identifying the critical parameters, the Work Assignment should specify the other variables to be investigated (e.g., materials handling, treatment of residuals).

3.5 PREPARING THE WORK PLAN

3.5.1 General

Carefully planned treatability studies are necessary to ensure that the data generated are useful for evaluating the validity or performance of a technology. The Work Plan, which is prepared by the contractor when the Work

Assignment is in place, sets forth the contractor's proposed technical approach for completing the tasks outlined in the Work Assignment. It also assigns responsibilities and establishes the project schedule and costs. Table 4 presents the suggested organization of a treatability study Work Plan. The Work Plan must be approved by the RPM before initiating subsequent tasks. Each of the principal Work Plan elements is described in the following subsections.

TABLE 4. SUGGESTED ORGANIZATION OF TREATABILITY STUDY WORK PLAN

1. Project Description
2. Remedial Technology Description
3. Test Objectives
4. Experimental Design and Procedures
5. Equipment and Materials
6. Sampling and Analysis
7. Data Management
8. Data Analysis and Interpretation
9. Health and Safety
10. Residuals Management
11. Community Relations
12. Reports
13. Schedule
14. Management and Staffing
15. Budget

Project Description--

The project description provides background information on the site and summarizes existing waste characterization data (type, concentration, and distribution of contaminants of concern). This information can be obtained from the Work Assignment or other background documents, such as the RI. The project description also specifies the type of study to be conducted (i.e., laboratory screening, bench-scale testing, or pilot-scale testing). For treatability studies involving multiple tiers of testing, it describes how the need for subsequent levels of testing will be determined from the results of the previous tier.

Remedial Technology Description--

This section briefly describes the remedial technology to be tested. A flow diagram showing the input stream, the output stream, and any side streams generated as a result of the treatment process can be included. For treatability studies involving treatment trains, the remedial technology description addresses all the unit operations the system comprises.

Test Objectives--

This section defines the objectives of the treatability study and the intended use of the data (i.e., to validate a technology, to evaluate performance, or to provide cost or design data). The test objectives are based on established cleanup goals for the site or, when such goals do not exist, on levels that are protective of human health and the environment.

Experimental Design and Procedures--

The experimental design identifies the volume of waste material to be tested, the critical parameters and levels of testing, and the type and amount of replication. Examples of critical parameters include pH, reagent dosage, temperature, and reaction (or residence) time. Some form of replication is usually incorporated into a treatability study to provide a greater level of confidence in the data. The following methods are used to collect two types of replicates:

- Dividing a sample in half or thirds at the end of the experiment and analyzing each fraction. This method provides information on laboratory error.
- Analyzing two or three samples prepared independently of each other under the same test conditions. This method provides information on total error.

The data quality objectives and the costs associated with replication must be considered in the design of the experiment. A matrix outlining the test conditions and the number of replicates, such as the example in Table 5, should be included in the Work Plan.

TABLE 5. EXAMPLE TEST MATRIX FOR
ZEOLITE AMENDMENT BENCH-SCALE TREATABILITY STUDY[a]

	I - zeolite			II - zeolite				
Soil	A%	B%	C%	A%	B%	C%	III - limestone	IV - control
X	3	3	3	3	3	3	3	3
Y	3	3	3	3	3	3	3	3

[a] Numbers indicate number of replicates.

The specific steps to be followed in the performance of the treatability study are described in the standard operating procedures (SOP). The SOP should be sufficiently detailed to permit the laboratory of field technician to conduct the test, to operate the equipment, and to collect the samples with minimal supervision, as the example in Table 6 illustrates. The SOP can be appended to the Work Plan.

Equipment and Materials--

This section lists the equipment, materials, and reagents that will be used in the performance of the treatability study. The following specifications should be provided for each item listed:

TABLE 6. EXAMPLE STANDARD OPERATING PROCEDURE FOR THERMAL DESORPTION BENCH-SCALE TREATABILITY STUDY

1. Define and record planned experiment in the data book (i.e., time, temperature, soil, etc.).

2. Weigh the empty clean tray.

3. Transfer a representative aliquot of prepared soil from the jar to the tray with a stainless steel spatula.

4. Weigh the soil and tray and adjust the soil quantity to achieve a uniform layer approximately 2.5 to 3 mm deep in the bottom of the tray.

5. Distribute and level the soil within the tray.

6. Turn on the purge-gas flow to the proper setting on the rotameter.

7. Place the tray with soil in the oven at ambient temperature and close the oven door.

8. Set the oven temperature controller set-point to the target test temperature and start the timer.

9. Monitor and record the temperatures and time periodically throughout the test period.

10. When the prescribed residence time at the target temperature is reached, shut off the oven heater and purge-gas flow and open the oven door.

11. Cautiously withdraw the hot tray and soil with special tongs, place a cover on the tray, and place the covered tray in a separate hood for cooling for approximately 1 hour.

12. Weigh the tray (without cover) plus treated soil.

13. Transfer an aliquot (typically about 20 grams) of treated soil from the tray to a tared, 60-cm^3, wide-mouth, amber bottle with Teflon-lined cap. Code, label, and submit this aliquot for analysis. Transfer the remainder of the treated soil to an identical type bottle, label, and store as a retainer.

14. Clean the tray, cover, and nondisposable implements by the following procedure:

    ° Rinse with acetone and wipe clean.
    ° Scrub with detergent (Alconox) solution and rinse with hot tap water followed by distilled water.
    ° Rinse with acetone and allow to dry.
    ° Rinse three times with methylene chloride (i.e., approximately 15 to 25 ml each rinse for the tray).
    ° Air dry and store.

- Quantity
- Volume/capacity
- Calibration or scale
- Equipment manufacturer and model number
- Reagent grade and concentration

Table 7 provides an example listing of equipment and materials for a laboratory screening study involving chemical treatment with potassium polyethylene glycolate (KPEG). In addition, a diagram of the test apparatus, similar to that shown in Figure 5, should be included in the Work Plan.

Sampling and Analysis--

A Sampling and Analysis Plan is required for all field activities conducted during the RI/FS. This section describes how the existing Sampling and Analysis Plan will be modified to address field sampling, waste characterization, and sampling and analysis activities in support of the treatability study. It describes the kinds of samples that will be collected and specifies the level of QA/QC required. (Preparation of the Sampling and Analysis Plan is discussed in Subsection 3.6.)

Data Management--

Treatability studies must be well documented, particularly if the findings are likely to be challenged by a responsible party, the State, or the community. This section describes the procedures for recording observations and raw data in the field or laboratory, including the use of bound notebooks, data collection sheets, and photographs. Figure 6 shows an example of a form for daily logging of field activities. If proprietary processes are involved, this section also describes how confidential information will be handled.

Data Analysis and Interpretation--

This section describes the procedures that will be used to analyze and interpret data from the treatability study, including methods of data presentation (tabular and graphical) and statistical evaluation. (Data analysis and interpretation are discussed in Subsection 3.11.)

Health and Safety--

A Health and Safety Plan is required for all cleanup operations involving hazardous substances under CERCLA and for all operations involving hazardous wastes that are conducted at facilities regulated under RCRA. This section describes how the existing site or facility Health and Safety Plan will be modified to address the hazards associated with treatability testing. Hazards may include, but are not limited to, chemical exposure; fires, explosions, or spills; generation of toxic or asphyxiating gases; physical hazards; electrical hazards; and heat stress or frostbite. (Preparation of the Health and Safety Plan is discussed in Subsection 3.7.)

Residuals Management--

This section describes the management of treatability study residuals. Early recognition of the types and quantities of residuals that will be generated, the impacts that managing these residuals will have on the project

TABLE 7. EXAMPLE LIST OF EQUIPMENT AND MATERIALS FOR A KPEG LABORATORY SCREENING STUDY

1 multiport 2-liter glass reactor (Kimax 33700)
1 variable-speed stirrer with controller (Talboys 104)
1 Teflon-coated shaft for stirrer (Talboys 104)
1 76-mm multi-paddle Teflon agitator (Ace Glass, Inc.)
1 Teflon gasket for reaction flask (Ace Glass, Inc.)
1 cover clamp for reaction flask (Ace Glass, Inc.)
1 chain clamp (Fisher 5-745)
1 variable autotransformer, max. rating 1.4 kVa (Staco 3PN1010)
1 heating mantle, rating 470 watts at 115 V (Glas-Col)
1 water-cooled bearing, 34/45 joint (Ace Glass, Inc.)
1 condenser, Allihn, 24/40 joint (Corning 2480300)
1 Teflon-coated thermometer, -10° to 260°C
2 adapters, thermometers with screw-cap 24/40 joint (Kimax 44874)
1 adapter, offset, 24/40 joint (Ace Glass, Inc.)
1 pressure filtration system (Millipore YT30 142 HW)
1 Tenax tube with activated carbon
50 ft Tygon tubing, 5/16-in. i.d., 7/16-in. o.d.
2 rectangular supports, extra large
3 swivel clamp holders
3 3-finger extension clamps
1 2-stage pressure regulator for N_2 gas tank
1 stainless steel trowel or spoon
KPEG reagent
Nitrogen gas
Hexane
Acetone
12 sample jars with Teflon-lined lids, 8-oz

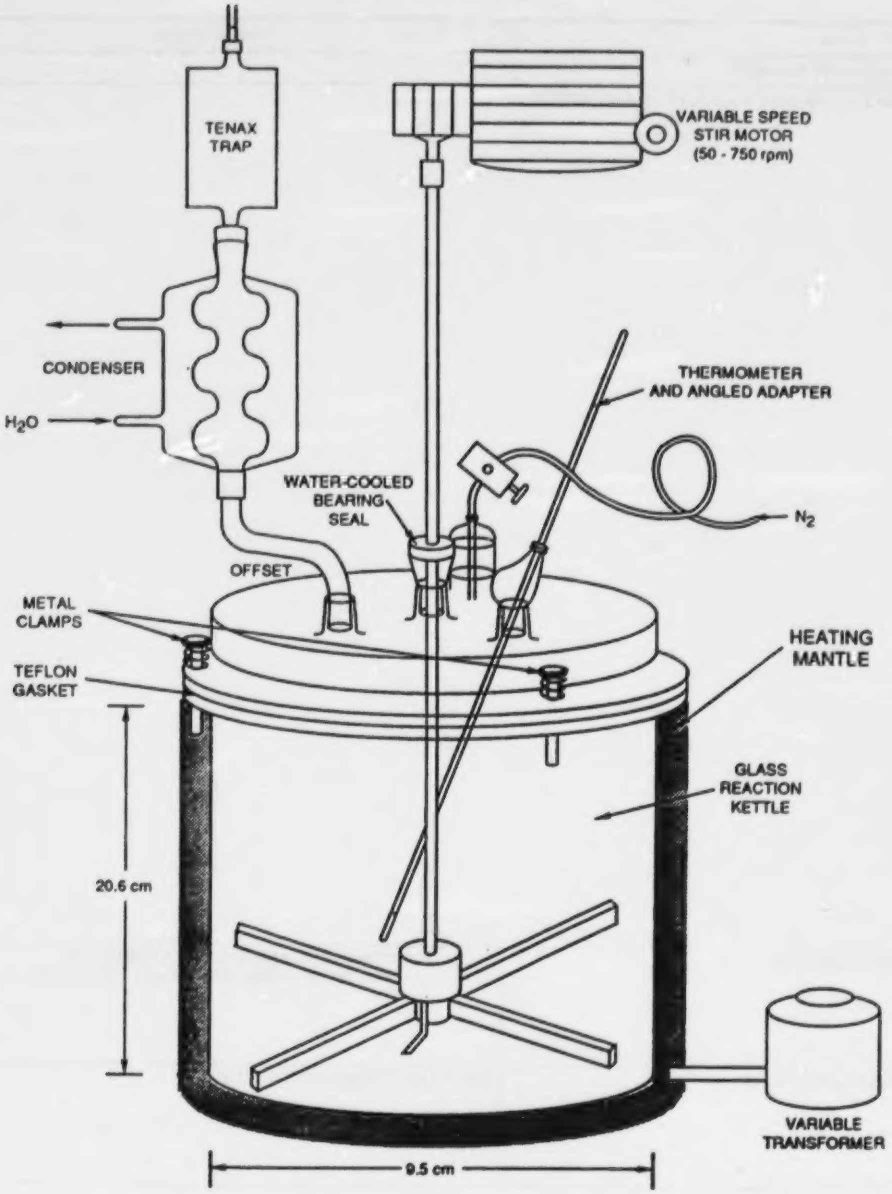
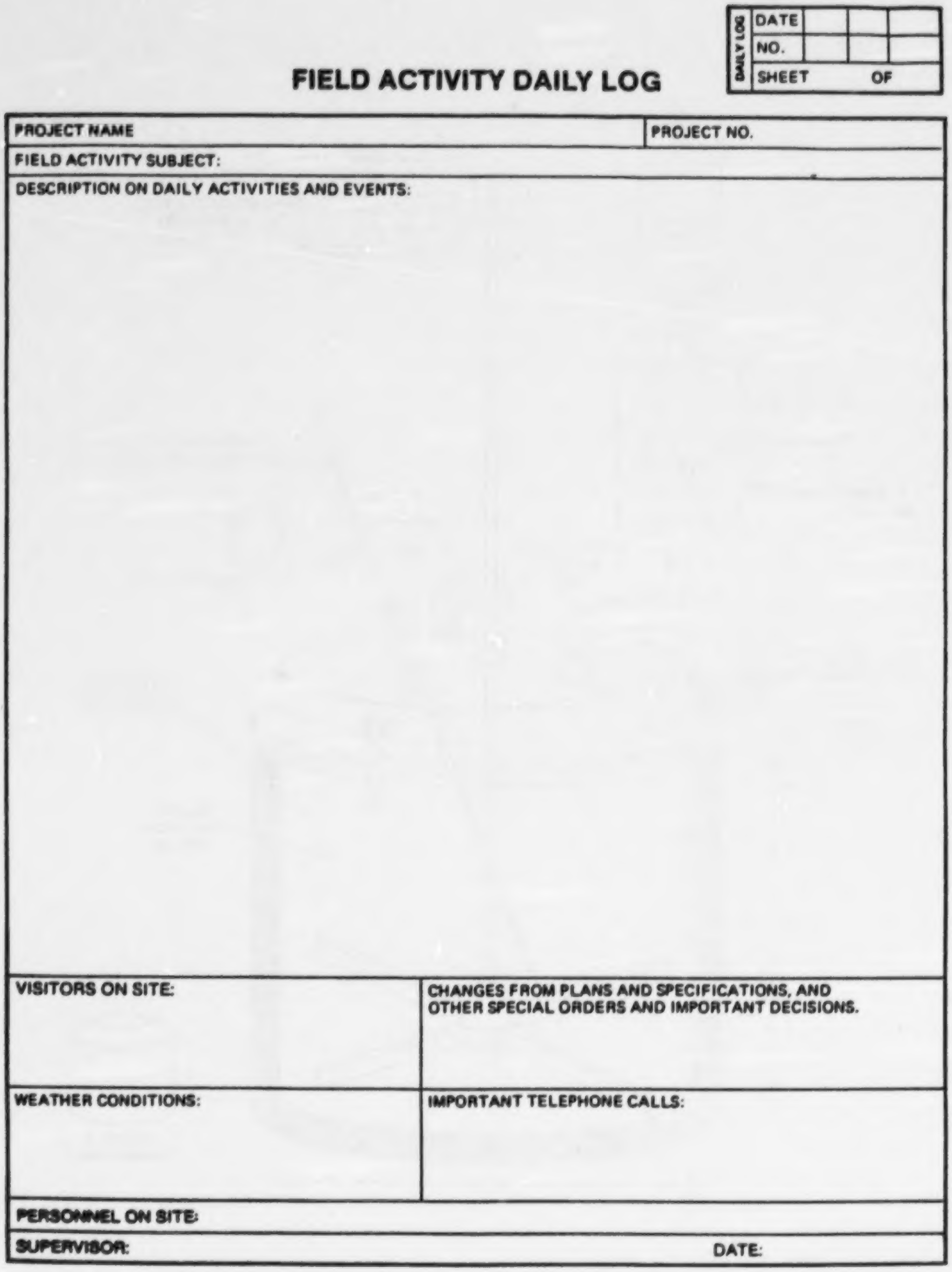

TENAX TRAP
VARIABLE SPEED STIR MOTOR (50 - 750 rpm)
CONDENSER
H_2O
THERMOMETER AND ANGLED ADAPTER
WATER-COOLED BEARING SEAL
N_2
OFFSET
METAL CLAMPS
TEFLON GASKET
HEATING MANTLE
GLASS REACTION KETTLE
20.6 cm
VARIABLE TRANSFORMER
9.5 cm

Figure 5. Example diagram of the test apparatus for a KPEG laboratory screening study.



DAILY LOG			
DATE			
NO.			
SHEET	OF		

FIELD ACTIVITY DAILY LOG

PROJECT NAME	PROJECT NO.
FIELD ACTIVITY SUBJECT:	
DESCRIPTION ON DAILY ACTIVITIES AND EVENTS:	
VISITORS ON SITE:	CHANGES FROM PLANS AND SPECIFICATIONS, AND OTHER SPECIAL ORDERS AND IMPORTANT DECISIONS.
WEATHER CONDITIONS:	IMPORTANT TELEPHONE CALLS:
PERSONNEL ON SITE:	
SUPERVISOR:	DATE:

Figure 6. Example of Field Activity Daily Log.

schedule and costs, and the roles and responsibilities of the various parties involved is important for disposing of residuals properly.

The Work Plan should include estimates of both the types and quantities of residuals expected to be generated during treatability testing. These projections should be based on knowledge of the treatment technology and the experimental design. Project residuals may include the following:

- Unused waste not subjected to testing
- Treated waste
- Treatment residuals (e.g., ash, scrubber water, combustion gases)
- Laboratory samples and sample extracts
- Used containers or other expendables
- Contaminated protective clothing and debris

This section describes how treatability study residuals will be analyzed to determine if they are hazardous wastes and specifies whether such wastes will be returned to the site or shipped to an acceptable treatment, storage, or disposal facility (TSDF) (see Subsection 3.9.1). In the latter case, this section also identifies the waste generator (lead agency, responsible party, or contractor) and delineates the parameters that will be analyzed for properly manifesting the waste and for obtaining disposal approval (see Table 8).

Community Relations--

A Community Relations Plan is required for all remedial response actions under CERCLA. This section describes the community relations activities that will be performed in conjunction with the treatability study. These activities may include, but are not limited to, preparation of fact sheets and news releases, conducting workshops or community meetings, and maintaining an up-to-date information repository. (Conducting community relations activities is discussed in Subsection 3.8.)

Reports--

This section describes the preparation of interim and final reports documenting the results of the treatability study. For treatability studies involving more than one tier (e.g., laboratory screening followed by bench-scale testing), interim reports (or project briefings) provide a means for determining whether to proceed to the next level of testing. This section also describes the preparation of monthly reports detailing current and projected progress on the project.

Schedule--

The schedule gives the anticipated starting date and ending date for each of the tasks described in the Work Plan and shows how the various tasks interface. The timespan for each task should take into account the time required to obtain the Work Plan, subcontractor, and other approvals (e.g., disposal approval from a commercial TSDF); sample curing time (for solidification/stabilization studies); analytical turnaround time; and review and comment period for reports and other project deliverables. Some slack time also should be built into the schedule to accommodate unexpected delays (e.g., bad weather, equipment downtime) without affecting the project completion date.

TABLE 8. WASTE PARAMETERS REQUIRED TO OBTAIN DISPOSAL APPROVAL AT AN OFFSITE FACILITY[a]

Incineration parameters
- Total solids
- % water
- pH
- % ash
- Total sulfide
- Specific gravity
- Total cyanide
- Flash point
- Total phenolics
- Total organic halogen (TOX)
- Btu/pound
- Total sulfur
- Total organic nitrogen
- Polychlorinated bipnehyls (PCBs)
- Total RCRA metals (eight)
- Priority pollutant organics
  - Volatile
  - Semivolatile (BN/A-extractable)
  - Remaining F-listed solvents

Treatment parameters
- Oil and grease
- Total organic carbon (TOC)
- pH
- Specific gravity
- Total metals (RCRA plus Cu, Ni, Zn)
- Cyanide
- Sulfide
- Total phenolics

Landfill parameters (solids only)
- % ash
- pH
- Specific gravity
- Total cyanide
- Total sulfide
- PCBs
- Total phenolics
- % water
- EP Tox metals (extraction and RCRA metals)
- TCLP F-listed solvents

---

[a] Analysis of these parameters is required unless they can be ruled out based on knowledge of the waste.

The schedule is usually displayed in the form of a bar chart such as that shown in Figure 7. In this example for a bench-scale treatability study, the actual testing will last 2 weeks; however, the entire project (from Work Plan preparation to residuals management) will span 30 weeks. Treatability studies that involve multiple tiers of testing should be shown on one schedule.

Management and Staffing--

This section identifies key management and technical personnel and defines specific project roles and responsibilities. The RPM is responsible for project planning and oversight. At Federal- and State-lead sites, the remedial contractor directs the treatability study; at private-lead sites, the responsible party performs this function. The treatability study may be subcontracted in whole or in part to a vendor, laboratory, or testing facility with expertise in the technology being evaluated. The line of authority is usually presented in an organization chart, such as that shown in Figure 8. Resumes may be appended to the Work Plan.

Budget--

The budget presents the projected costs for completing the treatability study as described in the Work Plan, including all labor, travel, equipment and materials, analyses, transportation and disposal, and administrative costs and fees. (Appendix B describes the various cost elements associated with conducting treatability studies.)

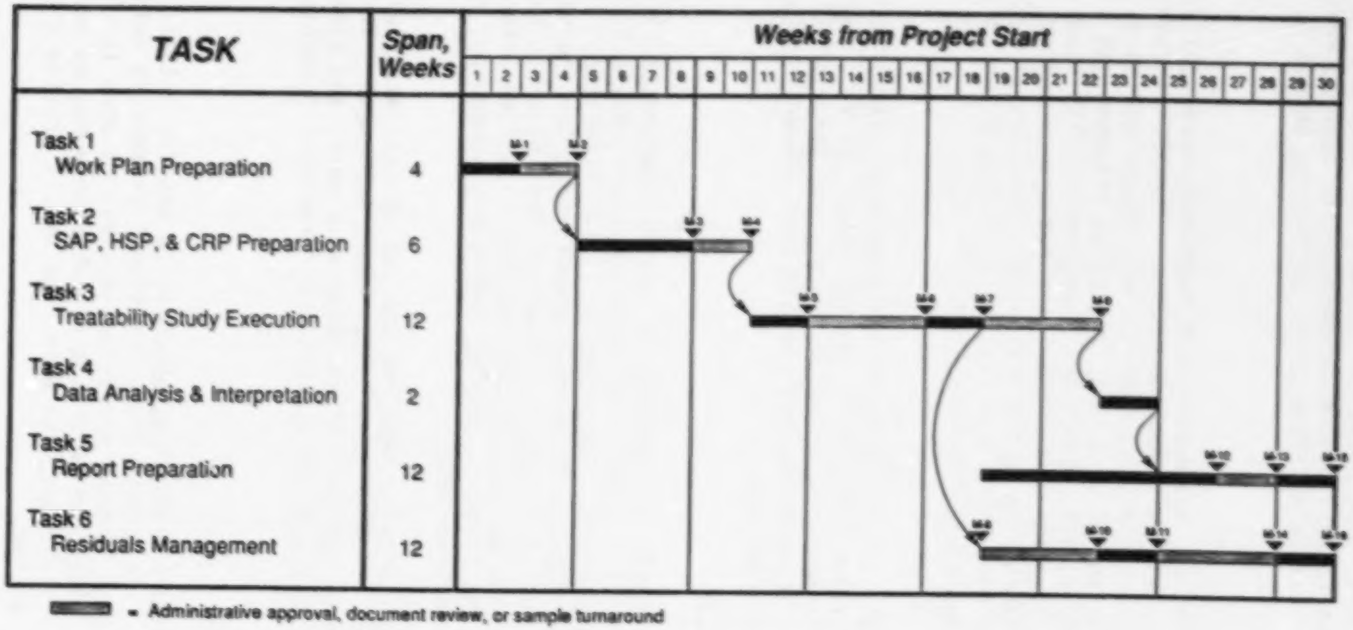
3.5.2 Laboratory Screening

Laboratory screening entails evaluation of several parameters at a few levels with little or no replication. The test conditions should bracket values reported in the literature. For example, if the literature indicates that a reaction time of 30 minutes is generally sufficient for the destruction of a particular compound by a specific process, testing could be conducted at 15, 30, and 60 minutes to determine how reaction time affects performance. Because of the limited scope of laboratory screening, rigorous statistical design is not appropriate.

Laboratory screening typically involves the use of laboratory glassware (such as jars and beakers) or other readily available equipment. The Work Plan should specify the type and size of containers, mixers, and other bench-top equipment, and the volume and concentration of treatment reagents or additives.

3.5.3 Bench-Scale Testing

Compared with laboratory screening, bench-scale testing entails evaluation of fewer parameters (i.e., only those "critical" parameters defined in the literature or determined through screening studies) at more levels and with greater replication. Because selection of the remedy may be based on the results of these investigations, the Work Plan should provide a statistically sound experimental design.



M-1	Submit Work Plan	Wk 2
M-2	Receive Work Plan Approval	Wk 4
M-3	Submit SAP, HSP, CRP	Wk 8
M-4	Receive SAP, HSP Approvals	Wk 10
M-5	Collect Sample	Wk 12
M-6	Receive Sample Characterization Results	Wk 16
M-7	Collect Treatability Study Samples	Wk 18
M-8	Collect Project Residual Samples	Wk 18
M-9	Receive Treatability Study Analytical Results	Wk 22
M-10	Receive Project Residual Analytical Results	Wk 22
M-11	Submit Waste Disposal Approval Form	Wk 24
M-12	Submit Draft Report	Wk 26
M-13	Receive Review Comments	Wk 28
M-14	Receive Waste Disposal Approval	Wk 28
M-15	Submit Final Report; Conduct Briefing	Wk 30
M-16	Ship Wastes to TSDF	Wk 30

Figure 7. Example project schedule for a bench-scale treatability study.

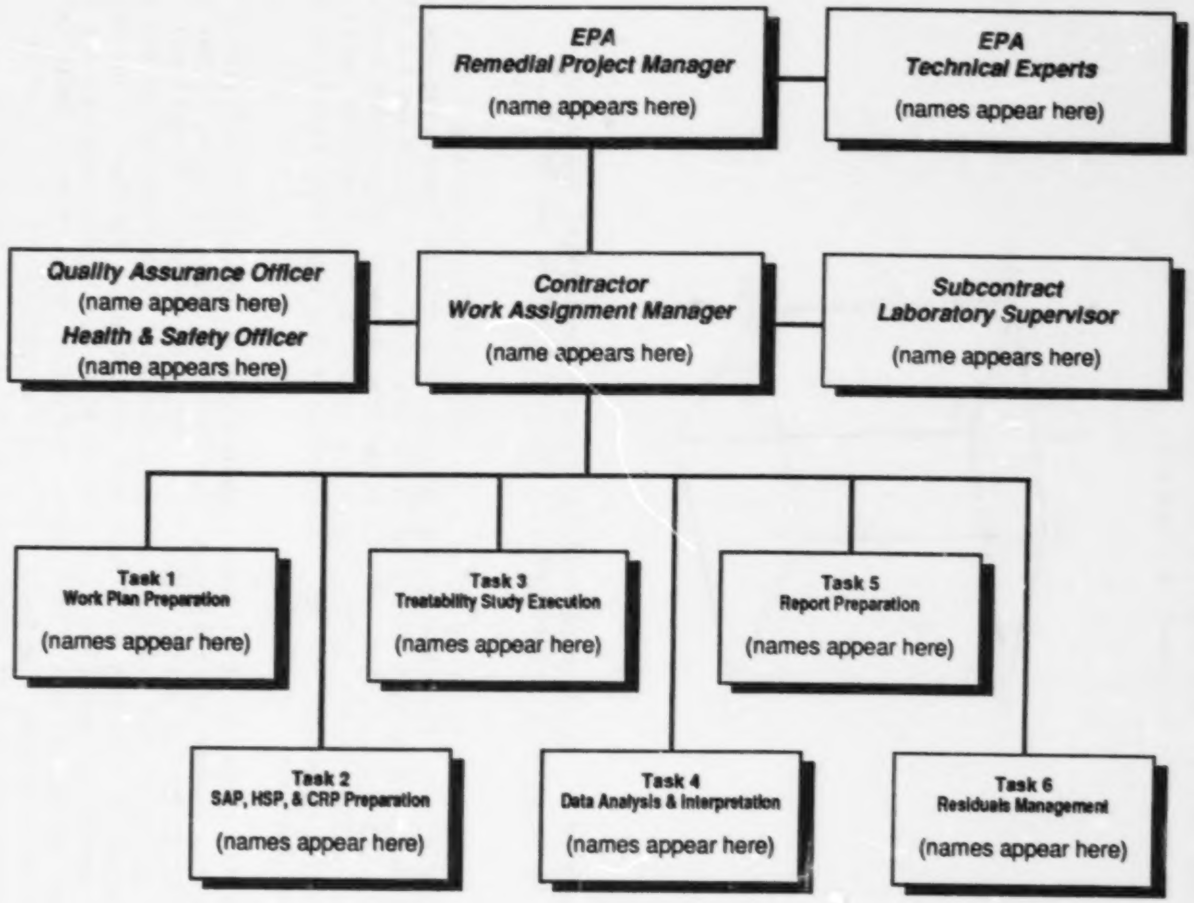

EPA
Remedial Project Manager
(name appears here)
EPA
Technical Experts
(names appear here)
Quality Assurance Officer
(name appears here)
Health & Safety Officer
(name appears here)
Contractor
Work Assignment Manager
(name appears here)
Subcontract
Laboratory Supervisor
(name appears here)
Task 1
Work Plan Preparation
(names appear here)
Task 2
SAP, HSP, & CRP Preparation
(names appear here)
Task 3
Treatability Study Execution
(names appear here)
Task 4
Data Analysis & Interpretation
(names appear here)
Task 5
Report Preparation
(names appear here)
Task 6
Residuals Management
(names appear here)

Figure 8. Example organization chart for a treatability study.

One of the more common experimental designs applicable to bench-scale treatability studies is the "factorial design." A factorial design is applicable when two or more primary independent variables are each tested at two or more levels. For example, consider a situation in which there are three primary independent variables (e.g., temperature, pH, and percentage water). The experimenter wants to observe the effect when each variable is tested at two levels. The experimental space for this experiment can be presented graphically as shown in Figure 9.

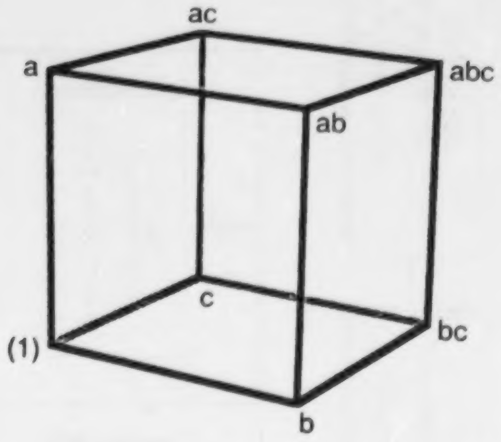


Figure 9. Graphic representation of experimental space for three primary independent variables tested at two levels.

This example is referred to as a 2^3 factorial design in eight (2 x 2 x 2) test conditions. For bench-scale treatability studies involving the use of triplicates, the actual number of individual test runs would be 3 x 2^3, or 24. Should the investigator need to study five primary independent variables, each at two levels, with triplicate analyses, the number of tests required would be 3 x 2^5, or 96. Obviously, it would be very costly to run an experiment of such magnitude.

The total number of test runs required can be reduced significantly by decreasing the number of replicates from three to two. Further, rather than run the full factorial design, the investigator could use a "fractional factorial design." For example, to run a one-half factorial design for the 2^3 full factorial requires only four test conditions. Further, a one-half factorial design for the 2^5 full factorial with duplicates requires $\frac{1}{2}$ x 2^5 x 2 = 32 test run conditions. Obviously, the use of a fractional factorial design not only reduces the number of test run conditions, but also results in a corresponding loss of information gained from the experiment.

Bench-scale testing typically involves the use of bench-top equipment or apparatus that simulates the basic operation of the treatment process. The Work Plan should describe how the equipment will be assembled and what materials will be used in its construction. The Work Plan also should specify the volume and concentration of treatment reagents or additives.

3.5.4 Pilot-Scale Testing

Compared with bench-scale testing, pilot-scale testing entails evaluation of the critical parameters at fewer levels but with even greater replication. Because selection of the remedy may be based on the results of these investigations, the Work Plan should provide a statistically sound experimental design (factorial or fractional factorial).

Pilot-scale testing typically involves the use of pilot-plant or field-testing equipment of a configuration similar to that of the full-scale operating unit. If the tests are to be conducted on site, the Work Plan should describe how the site will be prepared (including a map of the site layout), what utility hookups will be required, and how the equipment will be mobilized. The Work Plan also should specify the form in which treatment reagents or additives will be delivered and stored. If equipment shakedown is necessary, details should be given in this section.

3.6 PREPARING THE SAMPLING AND ANALYSIS PLAN

3.6.1 General

A Sampling and Analysis Plan (SAP) is required for all field activities conducted during the RI/FS. The purpose of the SAP is to ensure that samples obtained for characterization and testing are representative and that the quality of the analytical data generated is known. The SAP addresses field sampling, waste characterization, and sampling and analysis of the treated wastes and residuals from the testing apparatus or treatment unit.

Table 9 presents the suggested organization of the Sampling and Analysis Plan. The SAP consists of two parts--the Field Sampling Plan (FSP) and the Quality Assurance Project Plan (QAPjP).

Field Sampling Plan--

The FSP component of the SAP describes the sampling objectives; the type, location, and number of samples to be collected; the sample numbering system; the necessary equipment and procedures for collecting the samples; the sample chain-of-custody procedures; and the required packaging, labeling, and shipping procedures.

The sampling objectives must support the goals of the treatability study. For example, if the goal of laboratory screening is to determine the validity of biodegradation at a site, the objective of field sampling should be to collect samples representing "average" conditions at the site. If, however, the goal of the study is to determine the maximum time required to remediate the site, the objective of field sampling should be to collect samples representing the "worst case."

TABLE 9. SUGGESTED ORGANIZATION OF SAMPLING AND ANALYSIS PLAN

Field Sampling Plan

1. Site Background
2. Sampling Objectives
3. Sample Location and Frequency
4. Sample Designation
5. Sample Equipment and Procedures
6. Sample Handling and Analysis

Quality Assurance Project Plan

1. Project Description
2. Project Organization and Responsibilities
3. Quality Assurance Objectives
4. Site Selection and Sampling Procedures
5. Sample Custody
6. Calibration Procedures and Frequency
7. Analytical Procedures
8. Data Reduction, Validation, and Reporting
9. Internal Quality Control Checks
10. Performance and Systems Audits
11. Preventive Maintenance
12. Calculation of Data Quality Indicators
13. Corrective Action
14. Quality Control Reports to Management
15. References

Appendices

A. Data Quality Objectives
B. Example of SOP for Chain-of-Custody Procedures
C. EPA Methods Used
D. SOP for EPA Methods Used
E. QA Project Plan Approval Form

The samples collected must be representative of the conditions being evaluated. Guidance on representative samples and statistical sampling is contained in Test Methods for Evaluating Solid Waste (EPA 1986). Additional guidance for the selection of field methods, sampling procedures, and chain-of-custody requirements can be obtained from A Compendium of Superfund Field Operations Methods (EPA 1987b).

Quality Assurance Project Plan--

The second component of the SAP, the QAPjP, details the quality assurance objectives (precision, accuracy, representativeness, completeness, and comparability) for critical measurements and the quality control procedures established to achieve the desired QA objectives for a specific treatability study. Guidance for preparing the QAPjP can be obtained from Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans (EPA 1980). In general, QAPjPs are based on the type of project being conducted and on the intended use of the data generated by the project.

3.6.2 Laboratory Screening

Laboratory screening requires a low level of QA/QC. Because technologies that are determined to be valid through laboratory screening are usually evaluated further at the bench scale, the QA/QC requirements associated with this tier are less rigorous. Nevertheless, the test data should be well documented.

3.6.3 Bench-Scale Testing

Bench-scale testing requires a moderate to high level of QA/QC. Because the data generated in bench-scale testing are generally used for evaluation and selection of the remedy, the QA/QC associated with this tier should be fairly rigorous and the test data well documented.

3.6.4 Pilot-Scale Testing

Pilot-scale testing requires a moderate to high level of QA/QC. Because the data generated in pilot-scale testing are used in support of remedy selection and implementation, the QA/QC associated with this tier should be rigorous and the test data well documented.

3.7 PREPARING THE HEALTH AND SAFETY PLAN

3.7.1 General

A site-specific Health and Safety Plan (HSP) is required for all hazardous waste operations that involve employee exposure to safety or health hazards. The HSP identifies the hazards associated with each phase of site or facility operations and prescribes appropriate protective measures. Hazards that may be encountered during treatability studies include the following:

- Chemical exposure (inhalation, absorption, or ingestion of contaminated soils, sludges, or liquids)
- Fires, explosions, or spills
- Generation of toxic or asphyxiating gases
- Physical hazards such as sharp objects or slippery surfaces
- Electrical hazards such as high-voltage equipment
- Heat stress or frostbite

Table 10 presents the suggested organization of the HSP, which addresses the Occupational Safety and Health Administration (OSHA) requirements in 29 CFR 1910.120(b)(4). Guidance for preparing the HSP is contained in A Compendium of Superfund Field Operations Methods (EPA 1987b) and Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities (NIOSH/OSHA/USCG/EPA 1985). The HSP requirements apply to treatability studies conducted on site or at an offsite laboratory or testing facility permitted under RCRA, including research, development, and demonstration (RD&D) facilities. These requirements do not apply to facilities that are conditionally exempt from Subtitle C regulation by the treatability study sample exemption (see Subsection 3.9.2).

TABLE 10. SUGGESTED ORGANIZATION OF
HEALTH AND SAFETY PLAN

1. Hazard Analysis
2. Employee Training
3. Personal Protective Equipment
4. Medical Surveillance
5. Personnel and Environmental Monitoring
6. Site Control Measures
7. Decontamination Procedures
8. Emergency Response Plan
9. Confined-Space Entry Procedures
10. Spill Containment Program

Supervisors, equipment operators, and field technicians engaged in onsite operations must satisfy the training requirements in 29 CFR 1910.120(e) and must participate in a medical surveillance program, as described in 29 CFR 1910.120(f). Laboratory personnel must be trained with regard to container labeling and Material Safety Data Sheets (MSDS) in accordance with the OSHA hazard communication standard in 29 CFR 1910.1200. Before any treatability studies are initiated, the Site Safety Officer should conduct a briefing to ensure that investigators are apprised of the HSP. The Site Safety Officer also should conduct inspections during the course of the treatability study to determine compliance with and effectiveness of the HSP.

3.7.1 Laboratory Screening

The safety and health hazards associated with laboratory screening are relatively minor because of the small volumes of wastes that are subjected to testing. In general, the HSP should provide for skin and eye protection when handling the wastes. It need not require respiratory protection if the tests are conducted in a fume hood.

3.7.2 Bench-Scale Testing

Like laboratory screening, the HSP should provide for skin and eye protection when handling the wastes. It also may require respiratory protection for treatment processes tested at the bench scale that involve mixing or aeration (e.g., solidification/stabilization, aerobic biological treatment), which could generate dust or volatilize organic contaminants.

3.7.3 Pilot-Scale Testing

Compared with the previous two tiers, pilot-scale testing involves significantly larger volumes of waste, and the associated safety and health hazards are much greater. The HSP should provide for skin, eye, and respiratory protection (Level C or higher); decontamination procedures; and equipment emergency shutdown procedures.

3.8 CONDUCTING COMMUNITY RELATIONS ACTIVITIES

3.8.1 General

Community relations activities provide interested persons with the opportunity to comment on and provide input to decisions concerning site actions, including the performance of treatability studies. Public participation in the RI/FS process ensures that the community is provided with accurate and timely information about site activities.

The Agency designs and implements community relations activities according to CERCLA and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The NCP requires the lead Agency to prepare a Community Relations Plan (CRP) for all remedial response actions and for all removal actions longer than 45 days, regardless of whether RI/FS activities are Fund-financed or conducted by RPs (40 CFR 300.67). A CRP must be prepared before RI/FS activities are initiated at the site. This plan outlines all community relations activities to be conducted during the RI/FS and projects future activities that will be required during remedial design and construction. These future activities are outlined more clearly in a revised plan developed prior to the remedial design phase.

Guidance for preparing a CRP and conducting community relations activities can be acquired from Community Relations in Superfund: A Handbook (EPA 1988b). Table 11 presents the CRP organization suggested in this handbook.

TABLE 11. SUGGESTED ORGANIZATION OF COMMUNITY RELATIONS PLAN

1. Overview of Community Relations Plan
2. Capsule Site Description
3. Community Background
4. Highlights of the Community Relations Program
5. Community Relations Activities and Timing

Appendices
    A. Contact List of Key Community Leaders and Interested Parties
    B. Suggested Locations of Meetings and Information Repositories

Prior to preparation of the CRP, community interviews should be conducted. These interviews are informal discussions held with State and local officials, community leaders, media representatives, and interested citizens to assess public concern and desire to be involved in site response activities. Discussions with citizens regarding the possible need for conducting onsite treatability studies will allow the Agency to anticipate and respond better to community concerns as the treatability testing process proceeds.

The Capsule Site Description in the CRP should include a brief discussion of the possibility for treatability studies being conducted on site. It should also attempt to identify the types of technologies that may be investigated and the tiers at which the treatability studies may be performed.

Conducting treatability studies on site is a potentially controversial issue within a community and may demand a great deal of effort on the part of the Agency. As the RI/FS progresses, community relations activities should focus on providing information to the community concerning the technology screening process and on obtaining feedback on community concerns associated with potentially applicable treatment technologies. Activities may include, but are not limited to, the following:

- Preparing fact sheets and news releases describing treatment technologies identified during the literature/data base screening.

- Conducting a workshop to present concerned citizens and local officials with the Agency's considerations for selection of the treatment technologies to be studied.

- Holding small group meetings with involved members of the community at regular intervals throughout the RI/FS process to discuss treatability study findings and site decisions as they develop.

- Ensuring citizen access to treatability study information by maintaining a complete and up-to-date information repository.

Fact sheets on the planned treatability studies should be made available to the public and should include a discussion of treatability-specific issues such as the following:

- Onsite treatability testing and analysis
- Transportation of contaminated materials offsite
- Materials handling
- Residuals management
- RI/FS schedule changes resulting from the unexpected need for additional treatability studies
- Uncertainties (risk) pertaining to innovative technologies
- The degree of development of potentially applicable technologies identified for treatability testing
- Potential disruptions to the community

3.8.2 Laboratory Screening

Laboratory screening is relatively low-profile and, if conducted offsite, will require very few community relations activities. Distributing fact sheets and placing the results from laboratory screening in the information repository will generally be sufficient.

3.8.3 Bench-Scale Testing

Bench-scale testing may not be particularly controversial if conducted offsite. Onsite testing, however, may require more community relations activities. In addition to making fact sheets and test results available to the public, holding an open house to view the treatment process in operation may be advisable.

3.8.4 Pilot-Scale Testing

Pilot-scale testing may attract a great deal of community interest. In some cases (e.g., onsite thermal treatment), the strength of the public's opinion concerning pilot-scale testing of a potentially applicable technology may not have been indicated by the level of interest demonstrated during the RI and previous treatability studies. Because of the very real potential for conflict and misunderstanding at the pilot-scale testing stage of the RI/FS process, it is vital that a strong program of community relations and public participation be established well in advance of any treatability testing.

Pilot-scale testing may provide data that can convince a community of a technology's ability to remediate a site effectively. Inviting the community to view the pilot process and educating them about the technology through meetings and printed material may be helpful to foster community support for pilot-scale testing.

Early, open, and consistent communication with the public and their full participation in the decision-making process will help to prevent the testing, development, and selection of a remedy that is unacceptable to the community and results in delayed site remediation and higher remediation costs.

3.9 COMPLYING WITH REGULATORY REQUIREMENTS

3.9.1 General

Treatability studies involving CERCLA wastes are subject to certain permitting and operating requirements under the Comprehensive Environmental Response, Compensation, and Liability Act [as amended by the 1986 Superfund Amendments and Reauthorization Act (SARA)] and the Resource Conservation and Recovery Act (RCRA) [as amended by the 1984 Hazardous and Solid Waste Amendments (HSWA)]. These requirements vary depending on whether the studies are conducted on site (e.g., in a mobile trailer) or at an offsite laboratory or testing facility. The decision to conduct treatability studies on site is influenced by several technical considerations, including the following:

- Volume of waste to be tested
- Availability of mobile laboratory or transportable treatment unit
- Site accessibility and size/space restrictions
- Availability of onsite utilities (e.g., water, electricity, telephone)
- Mobilization/demobilization and per diem costs
- Duration of tests
- State and community acceptance

Figure 10 summarizes the regulatory requirements for onsite and offsite testing; these requirements are described in the succeeding subsections.

Onsite Treatability Studies--

Onsite treatability studies under CERCLA may be conducted without any Federal, State, or local permits [40 CFR 300.68(a)(3)]; however, such studies must comply with applicable or relevant and appropriate requirements (ARARs) under Federal and State environmental laws. For example, treatability studies involving surface-water discharge must meet effluent limitations even though a discharge permit is not required.

Offsite Treatability Studies--

Section 121(d)(3) of CERCLA and the Revised Off-Site Policy (OSWER Directive 9834.11, November 13, 1987) generally state that offsite facilities that receive CERCLA wastes must be 1) operating in compliance with applicable Federal and State laws, and 2) controlling any relevant releases of hazardous substances to the environment. Currently, the Revised Off-Site Policy does not specifically exempt the transfer of CERCLA wastes offsite for treatability studies; therefore, offsite laboratories or testing facilities that receive CERCLA wastes must be in compliance with the offsite requirements. As part of a proposed rule to implement CERCLA Section 121(d)(3), however, the EPA has requested comment on whether CERCLA wastes sent to laboratories for analysis should be exempt from the offsite requirements (53 FR 48218, November 29, 1988). The commenters generally agree, and several have suggested that this exemption be extended to wastes sent to laboratories and testing facilities for treatability studies. Thus, the final rule, which is expected to be published in February 1990, may change the offsite requirements for wastes undergoing treatability testing and should be consulted on this point.

Offsite treatability studies under CERCLA must be conducted under appropriate Federal or State permits or authorization and other legal requirements. Effective July 19, 1988, the sample exclusion provision [40 CFR 261.4(d)], which exempts waste samples collected for the sole purpose of determining their characteristics or composition from regulation under Subtitle C of RCRA, was expanded to include waste samples used in small-scale treatability studies (53 FR 27301). Because it is considered less stringent than authorized State regulations for RCRA permits, the Federal Treatability Study Sample Exemption Rule is applicable only in those States that do not have final authorization or in authorized States that have revised their program to adopt equivalent regulations under State law. Although the provision is optional, the EPA has strongly encouraged authorized States to adopt the exemption or to exercise their authority to order treatability studies (in

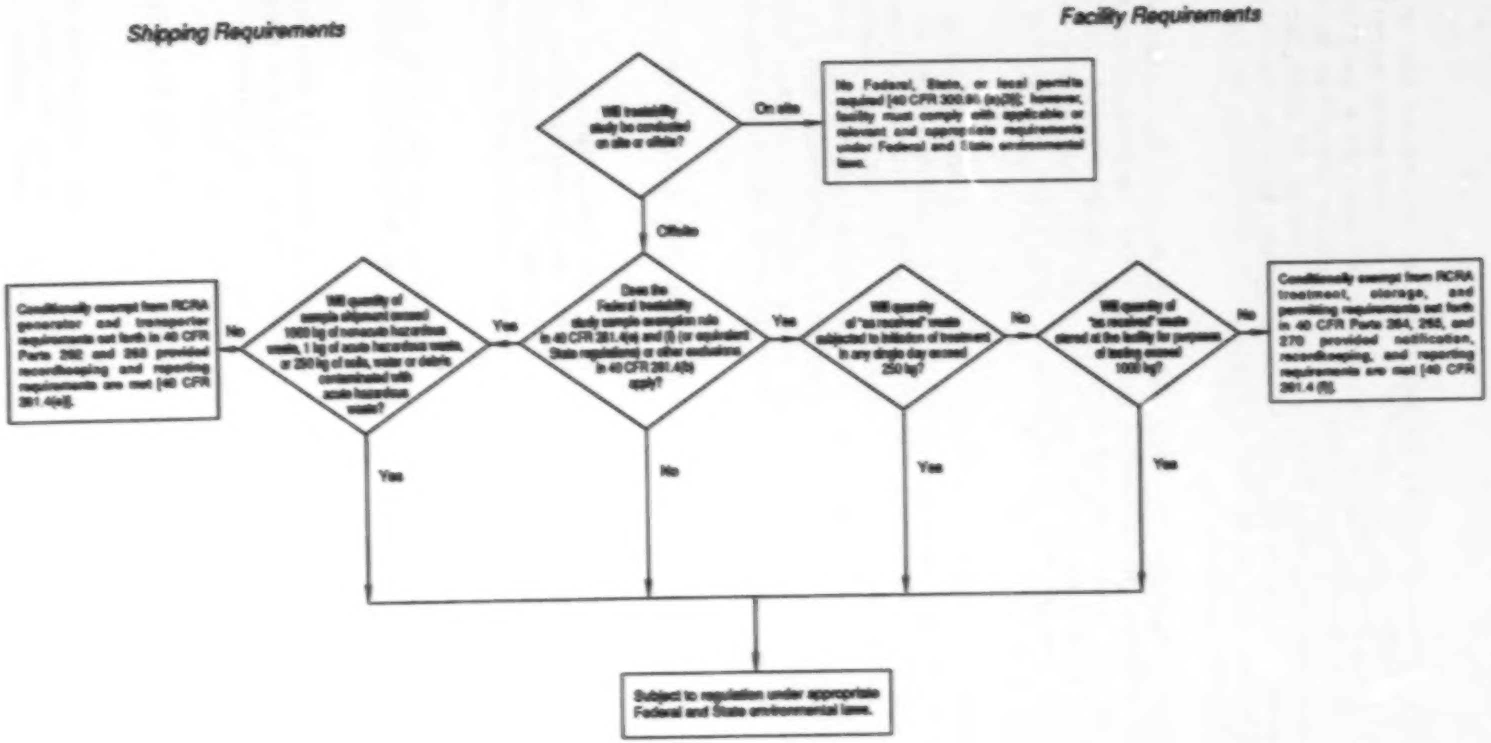

Shipping Requirements
Facility Requirements
Will treatability study be conducted on site or offsite?
On site
No Federal, State, or local permits required [40 CFR 300.61 (e)(2)]; however, facility must comply with applicable or relevant and appropriate requirements under Federal and State environmental laws.
Offsite
Does the Federal treatability study sample exemption rule in 40 CFR 261.4(e) and (f) (or equivalent State regulations) or other exclusions in 40 CFR 261.4(b) apply?
Yes
Will quantity of sample shipment exceed 1000 kg of nonacute hazardous waste, 1 kg of acute hazardous waste, or 250 kg of soils, water or debris contaminated with acute hazardous waste?
No
Conditionally exempt from RCRA generator and transporter requirements set forth in 40 CFR Parts 262 and 263 provided recordkeeping and reporting requirements are met [40 CFR 261.4(e)].
Yes
Will quantity of "as received" waste subjected to initiation of treatment in any single day exceed 250 kg?
No
Will quantity of "as received" waste stored at the facility for purposes of testing exceed 1000 kg?
No
Conditionally exempt from RCRA treatment, storage, and permitting requirements set forth in 40 CFR Parts 264, 265, and 270 provided notification, recordkeeping, and reporting requirements are met [40 CFR 261.4 (f)].
Yes
No
Yes
Yes
Subject to regulation under appropriate Federal and State environmental laws.

Figure 10. Regulatory requirements for onsite and offsite testing.

the case of imminent and substantial endangerment to health or the environment) or to grant a general waiver, permit waiver, or emergency permit authority to authorize treatability studies. To determine whether a particular State has adopted the Federal Treatability Study Sample Exemption Rule, the reader should contact the Regional Branch Chief in charge of RCRA Subtitle C authorization as given in Table 12; the State Programs Branch, Permits and State Programs Division, Office of Solid Waste (202/382-2210); or the State's environmental protection agency.

Under the Federal Treatability Study Sample Exemption Rule, persons who generate or collect samples of hazardous waste for the purpose of conducting treatability studies are conditionally exempt from the generator and transporter requirements (40 CFR Parts 262 and 263) when the samples are being collected, stored, or transported to an offsite laboratory or testing facility [40 CFR 261.4(e)] provided that:

1) The generator or sample collector uses no more than 1000 kg of any nonacute hazardous waste, 1 kg of acute hazardous waste, or 250 kg of soils, water, or debris contaminated with acute hazardous waste per waste stream per treatment process. (The Regional Administrator or State Director may, on a case-by-case basis, grant requests for waste stream limits up to an additional 500 kg of nonacute hazardous waste, 1 kg of acute hazardous waste, and 250 kg of soils, water, or debris contaminated with acute hazardous waste.)

2) The quantity of each sample shipment does not exceed these quantity limitations.

3) The sample is packaged so that it will not leak, spill, or vaporize from its packaging during shipment, and the transportation of each sample shipment complies with U.S. Department of Transportation (DOT), U.S. Postal Service (USPS), or any other applicable regulations for shipping hazardous materials.

4) The sample is shipped to a laboratory or testing facility that is exempt under 40 CFR 261.4(f) or that has an appropriate RCRA permit or interim status.

5) The generator or sample collector maintains copies of the shipping documents, the contract with the facility conducting the treatability study, and records showing compliance with the shipping limits for 3 years after completion of the treatability study.

6) The generator provides the above documentation in its biennial report.

Similarly, offsite laboratories or testing facilities (including mobile treatment units) are conditionally exempt from the treatment, storage, and permitting requirements (40 CFR Parts 264, 265, and 270) when conducting treatability studies [40 CFR 261.4(f)] provided that:

TABLE 12. REGIONAL RCRA CONTACTS FOR DETERMINING TREATABILITY STUDY SAMPLE EXEMPTION STATUS

U.S. EPA Region I
Massachusetts Waste Management Branch
(617) 573-1520
Connecticut Waste Management Branch
(617) 573-9650
New Hampshire and Rhode Island Waste Management Branch
(617) 573-9610
Maine and Vermont Waste Management Branch
(617) 573-5770
John F. Kennedy Federal Building
Boston, MA 02203

U.S. EPA Region II
Hazardous Waste Compliance Branch
26 Federal Plaza
New York, NY 10278
(212) 264-3384

U.S. EPA Region III
Waste Management Branch
841 Chestnut Street
Philadelphia, PA 19107
(215) 597-1812
(215) 597-0980

U.S. EPA Region IV
Residuals Management Branch
345 Courtland Street, N.E.
Atlanta, GA 30365
(404) 347-3016

U.S. EPA Region V
RCRA Program Management Branch
230 South Dearborn Street
Chicago, IL 60604
(312) 353-8510

U.S. EPA Region VI
RCRA Programs Branch
First Interstate Bank Tower
14445 Ross Avenue
Dallas, TX 75202-2733
(214) 655-6656

U.S. EPA Region VII
RCRA Branch
726 Minnesota Avenue
Kansas City, KS 66101
(913) 236-2930

U.S. EPA Region VIII
RCRA Implementation Branch
One Denver Place, Suite 500
999 18th Street
Denver, CO 80202-2405
(303) 293-1662

U.S. EPA Region IX
State Programs Branch
215 Fremont Street
San Francisco, CA 94105
(415) 974-8917
(415) 974-1870

U.S. EPA Region X
Waste Management Branch
1200 Sixth Avenue
Seattle, WA 98101
(206) 442-2782

1) The facility notifies the Regional Administrator or State Director that it intends to conduct treatability studies.

2) The laboratory or testing facility has an EPA identification number.

3) The quantity of "as received" hazardous waste that is subjected to initiation of treatment in all treatability studies in any single day is less than 250 kg.

4) The quantity of "as received" hazardous waste that is stored at the facility does not exceed 1000 kg, the total of which can include 500 kg of soils, water, or debris contaminated with acute hazardous waste or 1 kg of acute hazardous waste.

5) No more than 90 days have elapsed since the treatability study was completed, or no more than 1 year has elapsed since the generator or sample collector shipped the sample to the laboratory or testing facility.

6) The treatability study does not involve either placement of hazardous waste on the land or open burning of hazardous waste.

7) The facility maintains records showing compliance with the treatment rate limits and the storage time and quantity limits for 3 years following completion of each study.

8) The facility keeps a copy of the treatability study contract and all shipping papers for 3 years from the completion date of each treatability study.

9) The facility submits an annual report to the Regional Administrator or State Director that estimates the number of studies and the amount of waste to be used in treatability studies during the current year and that provides information on treatability studies conducted during the previous year.

10) The facility determines whether any unused sample or residues generated by the treatability study are hazardous waste [unless they are returned to the sample originator under the 40 CFR 261.4(e) exemption].

11) The facility notifies the Regional Administrator or State Director when it is no longer planning to conduct any treatability studies at the site.

Laboratories or testing facilities not operating within these limitations are subject to appropriate regulation. For example, facilities having numerous treatment units that conduct many studies concurrently probably will exceed the storage and treatment rate limits; these facilities may be required to obtain a RCRA RD&D permit (40 CFR 270.65).

Residuals Management--

Treatability study residuals, including any unused sample or residues, generated at an offsite laboratory or testing facility may be returned to the sample originator under the Federal Treatability Study Sample Exemption Rule (or equivalent State regulations) provided the storage time limits in 40 CFR 261.4(f) are not exceeded. If the exemption does not apply, the disposal of treatability study residuals is subject to appropriate regulation (i.e., hazardous wastes must be disposed of at a facility permitted under Subtitle C of RCRA; solid wastes must be disposed of at a sanitary landfill or other facility in compliance with Subtitle D of RCRA). The acceptability of a commercial facility for receiving CERCLA wastes can be determined by contacting the appropriate Regional Offsite Contact (ROC) as given in Table 13. Treatability study residuals managed offsite must be packaged, labeled, and manifested in accordance with 40 CFR Part 262 and applicable DOT regulations for hazardous materials under 49 CFR Part 172.

As discussed previously, the Revised Off-Site Policy does not specifically exempt the transfer of treatability study residuals offsite for disposal; therefore, offsite treatment or disposal facilities that receive these wastes must be in compliance with the offsite requirements. The final offsite rule, which is expected to be published in February 1990, may change the offsite requirements for treatability study residuals and should be consulted on this point.

3.9.2 Laboratory Screening

Because it uses small volumes of waste, laboratory screening conducted offsite will typically be exempt from Subtitle C regulation provided the State in which the treatability study is to be conducted has adopted regulations equivalent to the Federal Treatability Study Sample Exemption Rule.

3.9.3 Bench-Scale Testing

As with laboratory screening, bench-scale testing conducted offsite will typically be exempt from Subtitle C regulation because of the small volumes of waste they use. When testing at the bench scale involves several process alternatives (e.g., stabilization with cement, pozzolan, or asphalt) for treating a particular waste stream, these may be considered separate treatment processes with respect to the quantity limitations in 40 CFR 261.4(e)(2)(i).

3.9.4 Pilot-Scale Testing

Because of the large volumes of wastes used, pilot-scale testing conducted offsite will typically be subject to Subtitle C regulation.* Also,

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* The Agency intends to address large-scale treatability studies in separate rulemaking at some future date; the Agency also is considering developing regulations under 40 CFR Part 264, Subpart Y, that would establish permitting standards for experimental facilities conducting research and development on the storage, treatment, or disposal of hazardous waste.

TABLE 13. REGIONAL OFFSITE CONTACTS FOR DETERMINING ACCEPTABILITY OF COMMERCIAL FACILITIES TO RECEIVE CERCLA WASTES[a]

Region	Primary contact/phone	Backup contact/phone
I	John Zipeto (617) 573-5744	Linda Murphy (617) 573-5703
II	Steven Lufftig (212) 264-8672	Dit Cheung (212) 264-6142 Joe Golumbek (212) 264-2638
III	Vernon Butler (215) 597-6681	Ruth Rzepski (215) 597-6413
IV	Alan Antley (404) 347-7603	Gregory Fraley (404) 347-7603
V	Gertrude Matuschkovitz (312) 353-7921	Joe Boyle (312) 886-4449
VI	Trish Brechlin (214) 655-6765	Randy Brown (214) 655-6745 Sam Becker (214) 655-6725
VII	David Doyle (913) 236-2891	Marc Rivas (913) 236-2891
VIII	Mel Poundstone (303) 293-1704	Mike Gansecki (303) 293-1510 Terry Brown (303) 293-1823
IX	Leif Magnuson (415) 974-7232	Jane Diamond (415) 974-8364
X	Al Odmark (206) 442-1886	Wayne Pierre (206) 442-7261

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[a] These contacts are subject to change. An updated list can be obtained from the Superfund docket or the RCRA/CERCLA Hotline (1-800-424-9346).

treatability studies involving the placement of wastes on the land (e.g., disposal of stabilized material in a landfill) will be subject to regulation. Laboratories or testing facilities conducting these types of studies must be permitted or have interim status with respect to the particular waste stream(s) and treatment process(es) to be tested.

3.10 EXECUTING THE STUDY

3.10.1 General

Execution of the treatability study begins after the RPM has approved the Work Plan and other supporting documents. Steps include collecting a sample of the waste stream for characterization and testing, conducting the test, and collecting and analyzing samples of the treated waste and residuals.

Field Sampling and Waste Stream Characterization--

Field samples should be collected and preserved in accordance with the procedures outlined in the SAP. They should be representative of "average" or "worst-case" condition, as dictated by the test objectives, and a large enough sample should be collected to complete all of the required tests and analyses in the event of some anomaly. To the extent possible, field sampling should be coordinated with other onsite activities to minimize costs. Samples shipped to an offsite laboratory for testing or analysis must be packaged, labeled, and shipped in accordance with DOT, USPS, or other applicable shipping regulations (see Subsection 3.9). A chain-of-custody record, such as the example in Figure 11, should accompany each sample shipment.

The collected sample should be thoroughly mixed to ensure that it is homogeneous. This will allow comparison of results under different test conditions. Small-volume soil samples can be mixed with a Hobart mixer, and large-volume samples can be mixed with a drum roller. Stones, sticks, and other debris should be removed by screening.

Characterization samples should be collected from the same material that will be used in the performance of the treatability study. Characterization is necessary to determine the chemical, physical, and/or biological properties exhibited by the waste stream so that the results of the treatability study can be properly gauged. Appendix C lists specific characterization parameters that may be applicable for biological treatment, physical/chemical treatment, immobilization, thermal treatment, and in situ treatment technologies. Standard analytical methods are referenced in Appendix D.

Treatability Testing--

The treatability study should be performed in accordance with the test matrix and standard operating procedures described in the Work Plan. Any deviations from the SOP should be recorded in the field or laboratory notebook. (Data management was discussed in Subsection 3.5.1.)

CHAIN-OF-CUSTODY RECORD

PROJECT NAME/NUMBER ______ LAB DESTINATION ______

SAMPLE TEAM MEMBERS ______ CARRIER/WAYBILL NO. ______

SAMPLE NUMBER	SAMPLE LOCATION AND DESCRIPTION	DATE AND TIME COLLECTED	SAMPLE TYPE	CONTAINER TYPE	CONDITION ON RECEIPT (NAME AND DATE)

SPECIAL INSTRUCTIONS: ______

POSSIBLE SAMPLE HAZARDS ______

SIGNATURES: (NAME,COMPANY,DATE,AND TIME) ______

1. RELINQUISHED BY: ______ 3. RELINQUISHED BY: ______

RECEIVED BY: ______ RECEIVED BY: ______

2. RELINQUISHED BY: ______ 4. RELINQUISHED BY: ______

RECEIVED BY: ______ RECEIVED BY: ______

WHITE - To accompany samples
YELLOW - Field copy

Figure 11. Example of Chain-of-Custody Record.

The EPA or a qualified contractor should oversee testing conducted by vendors and RPs. Oversight activities may include:

- Review of plans, reports, and records
- Oversight of waste sampling and analysis (e.g., split samples)
- Maintenance of records and documentation
- Validation of test results
- Monitoring of compliance with ARARs

Sampling and Analysis--

Samples of the treated waste and any process residuals (e.g., off-gas, scrubber water, and ash for incineration tests) should be collected in accordance with the SAP. The SAP specifies the location and frequency of sampling, proper containers and sample preservation techniques, and maximum holding times. Quality assurance samples (e.g., blanks, splits) should be collected at the same time as the treatability study samples. All samples should be logged in the field or laboratory notebook. As stated previously, samples shipped to an offsite laboratory must be packaged, labeled, and shipped in accordance with DOT, USPS, or other applicable shipping regulations, and a chain-of-custody record should accompany each sample shipment.

Analysis of treatability study samples should proceed in accordance with the methods specified in the SAP. The normal sample turnaround time is 3 to 4 weeks for most analyses; the laboratory may charge a premium if results are required in less time.

3.10.2 Laboratory Screening

Laboratory screening is normally performed on the bench top with small volumes of waste. For this reason, obtaining a representative sample for characterization and testing can be difficult, and thorough mixing of the waste feed is important. Direct-reading instruments and indicator tests used in laboratory screening provide quick and relatively inexpensive analyses.

3.10.3 Bench-Scale Testing

Like laboratory screening, bench-scale testing is normally performed on the bench top with small volumes of waste, and obtaining a representative sample can be difficult. For this reason, thorough mixing of the waste feed is important. These tests involve quantitative analyses with more sophisticated instruments such as gas chromatography (GC), gas chromatography/mass spectrometry (GC/MS), atomic absorption (AA), or inductively coupled plasma (ICP). Testing oversight should be provided if the results of bench-scale testing will be used to support the ROD.

3.10.4 Pilot-Scale Testing

Pilot-scale testing is typically performed in a pilot plant or in the field and involves significantly larger volumes of waste than either laboratory screening or bench-scale testing. Consequently, obtaining a respresentative sample is much less difficult. These tests include quanititative analyses with more sophisticated instruments (as described previously). Testing oversight should be provided as a matter of routine.

3.11 ANALYZING AND INTERPRETING THE DATA

3.11.1 General

Upon completion of a treatability study, the data must be summarized and evaluated to determine the validity or performance of the treatment process.

The first goal of data analysis is to determine the quality of the data collected. All data should be checked to assess precision (relative percent difference for duplicate matrix spikes), accuracy (percent recovery of matrix spikes), and completeness (percentage of data that are valid). If the QA objectives specified in the QAPjP have not been met, the RPM and the Work Assignment Manager must determine the appropriate corrective action.

Data are generally summarized in tabular or graphic form. The exact presentation of the data will depend on the experimental design and the relationship between the variables being compared. Generally, independent variables, which are controlled by the experimenter, are plotted on the abscissa, whereas dependent variables, which fluctuate as a result of changing the independent variables, are plotted on the ordinate. Examples of independent variables are pH, temperature, reagent concentration, and reaction time. Examples of dependent variables are removal efficiency and substrate utilization.

Table 14 presents an example tabulation of data from an experiment in which one parameter is varied (e.g., reagent concentration). A procedure referred to as analysis of variance (ANOVA) can be used to determine if a statistically significant difference exists between the effectiveness of the four reagent concentrations. Procedures for performing analyses of variance for one-way classifications are described by Snedecor and Cochran (1967).

TABLE 14. EXAMPLE TABULATION OF DATA FROM AN EXPERIMENT IN WHICH ONE PARAMETER IS VARIED[a]

	Reagent concentration, %			
Sample No.	A	B	C	D
1	x_{A1}	x_{B1}	x_{C1}	x_{D1}
2	x_{A2}	x_{B2}	x_{C2}	x_{D2}
3	x_{A3}	x_{B3}	x_{C3}	x_{D3}
Mean	$\bar{x}_A$	$\bar{x}_B$	$\bar{x}_C$	$\bar{x}_D$

[a] Reagent concentration is varied.

Table 15 presents an example tabulation of data from an experiment in which two parameters are varied (e.g., reagent concentration and reaction time). Analysis of variance techniques for two-way classifications (Snedecor and Cochran 1967) can be used to determine if reaction time has the same effect for both reagent concentrations and if a statistically significant difference exists between the mean effectiveness of the five reaction times. If such a difference is detected, ANOVA can be followed by the Tukey multiple-comparison procedure (Scheffe 1959) to determine which sample means differ significantly and by how much.

TABLE 15. EXAMPLE TABULATION OF DATA FROM AN EXPERIMENT IN WHICH TWO PARAMETERS ARE VARIED[a]

	Reagent concentration, %	
Reaction time, h	A	B
0.25	$x_{A,0.25,1}$	$x_{B,0.25,1}$
	$x_{A,0.25,2}$	$x_{B,0.25,2}$
	$x_{A,0.25,3}$	$x_{B,0.25,3}$
0.5	$x_{A,0.5,1}$	$x_{B,0.5,1}$
	$x_{A,0.5,2}$	$x_{B,0.5,2}$
	$x_{A,0.5,3}$	$x_{B,0.5,3}$
1	$x_{A,1,1}$	$x_{B,1,1}$
	$x_{A,1,2}$	$x_{B,1,2}$
	$x_{A,1,3}$	$x_{B,1,3}$
2	$x_{A,2,1}$	$x_{B,2,1}$
	$x_{A,2,2}$	$x_{B,2,2}$
	$x_{A,2,3}$	$x_{B,2,3}$
3	$x_{A,3,1}$	$x_{B,3,1}$
	$x_{A,3,2}$	$x_{B,3,2}$
	$x_{A,3,3}$	$x_{B,3,3}$

[a] Reagent concentration and reaction time are varied.

Data from an experiment in which multiple samples with different initial contaminant concentrations are tested under the same set of conditions are plotted as shown in Figure 12. Regression analysis, as described by Natrella

(1966), can be used to determine the effect of initial contaminant concentration on the performance of the technology. In its simplest form, regression analysis assumes a linear functional relationship:

$$y = \beta_0 + \beta_1 \cdot x$$

The statistical analysis procedure uses the experimental data to obtain estimates of the parameters β_0 (the y-intercept) and β_1 (the slope) of a straight line. This procedure is also referred to as "least-squares linear regression." The linear equation may be used to estimate the contaminant's final concentration in the waste stream, given its initial concentration. In this manner, one can determine whether a particular treatment technology under consideration has the potential to meet the cleanup goals for the site.

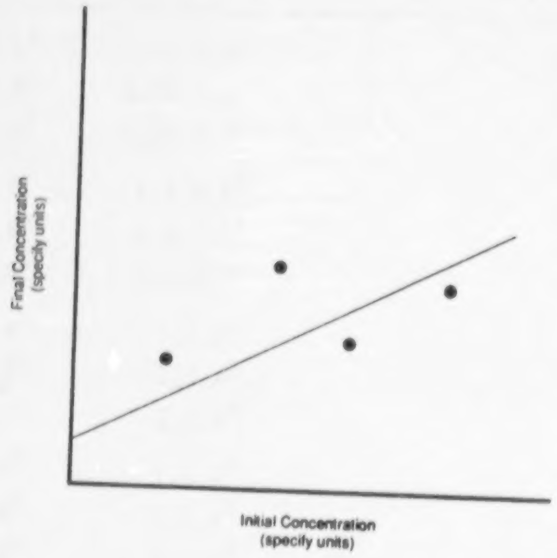

Figure 12. Example plot of initial versus final contaminant concentration.

In some instances, it may be unrealistic to assume that the relationship between a dependent and an independent variable can be expressed as a linear function. Procedures for nonlinear functions are discussed in most statistical texts.

3.11.2 Laboratory Screening

Laboratory screening is used to determine whether a technology is valid and if further testing is warranted. Because these studies entail limited

QA/QC and little or no replication, statistical analysis of the data may not be appropriate. Results can be interpreted qualitatively (i.e., "go/no go").

3.11.3 Bench-Scale Testing

Bench-scale testing usually involves factorial (or fractional factorial) design in which two or more primary independent variables are each tested at two or more levels. Cochran and Cox (1957) describe the application of ANOVA techniques to these types of studies. The data can be analyzed to determine how the critical parameters affect the performance of the system and if the process can meet the cleanup goals for the site.

3.11.4 Pilot-Scale Testing

Like bench-scale testing, pilot-scale testing usually involves factorial (or fractional factorial) design, and ANOVA techniques can be used to determine how the critical parameters affect the performance of the system. In addition, data from pilot-scale testing can provide information on costs (reagent use, power and water consumption, treatment rate, etc.) and equipment design (waste feed, mixing, solids separation, etc.).

3.12 REPORTING THE RESULTS

3.12.1 General

The final step in conducting a treatability study is reporting the test results. Complete and accurate reporting is critical, as decisions about treatment alternatives will be based, in part, on the outcome of treatability studies. Besides assisting in the selection of the remedy, the performance of treatability studies will increase the existing body of scientific knowledge about innovative treatment technologies.

For facilitation of the reporting of treatability study results and the exchange of treatment technology information, a suggested organization for a treatability study report is presented in Table 16. Reporting treatability study results in this manner will expedite the process of comparing treatment alternatives. It will also allow other individuals who may be studying similar technologies or waste matrices to gain valuable insight into the applications and limitations of various treatment processes.

If a treatment technology is to be tested at multiple tiers, it may not be necessary to prepare a formal report for each tier of the testing. Interim reports prepared at the completion of each tier may suffice. Also, it may be appropriate to conduct a project briefing with the interested parties to present the study findings and to determine the need for additional testing. A final treatability study report that encompasses the entire study may be developed after all testing is complete.

As an aid in the selection of remedies and the planning of future treatability studies, the Office of Emergency and Remedial Response requires that a copy of all treatability study reports be submitted to the Agency's

TABLE 16. SUGGESTED ORGANIZATION OF TREATABILITY STUDY REPORT

- 1. Introduction
  - 1.1 Site description
    - 1.1.1 Site name and location
    - 1.1.2 History of operations
    - 1.1.3 Prior removal and remediation activities
  - 1.2 Waste stream description
    - 1.2.1 Waste matrices
    - 1.2.2 Pollutants/chemicals
  - 1.3 Remedial technology description
    - 1.3.1 Treatment process and scale
    - 1.3.2 Operating features
  - 1.4 Previous treatability studies at the site
- 2. Conclusions and Recommendations
  - 2.1 Conclusions
  - 2.2 Recommendations
- 3. Treatability Study Approach
  - 3.1 Test objectives and rationale
  - 3.2 Experimental design and procedures
  - 3.3 Equipment and materials
  - 3.4 Sampling and analysis
    - 3.4.1 Waste stream
    - 3.4.2 Treatment process
  - 3.5 Data management
  - 3.6 Deviations from the Work Plan
- 4. Results and Discussion
  - 4.1 Data analysis and interpretation
    - 4.1.1 Analysis of waste stream characteristics
    - 4.1.2 Analysis of treatability study data
    - 4.1.3 Comparison to test objectives
  - 4.2 Quality assurance/quality control
  - 4.3 Costs/schedule for performing the treatability study
  - 4.4 Key contacts
- References
- Appendices
  - A. Data summaries
  - B. Standard operating procedures

Superfund Treatability Data Base repository, which is being developed by the Office of Research and Development (EPA 1989b). Submitting treatability study reports in accordance with the suggested organization will increase the usability of this repository and assist in maintaining and updating the data base. One camera-ready master copy of each treatability study report should be sent to the following address:

Mr. Kenneth A. Dostal
Superfund Treatability Data Base
U.S. Environmental Protection Agency
Office of Research and Development
Risk Reduction Engineering Laboratory
26 W. Martin Luther King Drive
Cincinnati, Ohio 45268

The following subsections describe the contents of the treatability study report.

Introduction--

The introductory section of the treatability study report contains background information about the site, waste stream, and treatment technology. Much of this information will come directly from the previously prepared treatability study Work Plan. This section also includes a summary of any treatability studies previously conducted at the site.

Conclusions and Recommendations--

This section presents the conclusions and recommendations concerning the applicability of the treatment process tested. It should attempt to answer questions such as the following:

- Were the test objectives met? If not, why?
- What parts of the test should have been performed differently and why?
- Are additional tiers of treatability testing required for further evaluation of the technology? Why or why not?
- Can the technology be scaled up based on the existing data?

The conclusions and recommendations should be stated briefly and succinctly. Information that is pertinent to the discussion and exists elsewhere in the report should be referenced rather than restated in this section.

The report should provide an analysis of the results as they relate to the goals of the study and the relevant evaluation criteria. In particular, the results should be extrapolated to full-scale operation to indicate areas and extent of uncertainty in the analysis.

Treatability Study Approach--

This section documents why and how the treatability study was conducted. It describes in detail the procedures and methods that were used to sample and analyze the waste stream and documents any deviations from the Work Plan.

Like the introduction, this section contains information from the previously prepared Work Plan.

Results and Discussion--

The final section of the treatability study report includes the presentation and a discussion of results (including QA/QC). Results for the contaminants of concern should be reported in terms of the concentration of the input and output streams as well as the percentage reduction achieved. The use of charts and graphs may aid in the presentation of results. This final report section also includes the costs and time requirements of conducting the study, as well as key contacts for future reference.

References--

All citations should be clearly referenced.

Appendices--

Summaries of the data generated and the standard operating procedures used are included in appendices.

3.12.2 Laboratory Screening

Laboratory screening results will be reported in the format shown in Table 16, although some of the sections may be abbreviated if bench- or pilot-scale testing is planned. The conclusions and recommendations will focus primarily on whether the technology investigated has validity for the site and will attempt to identify critical parameters for future treatability testing and to recommend tiers for future study. Data will be presented in simple tables or graphs. Statistical analysis is generally not required. Because laboratory screening does not involve rigorous QA/QC, the discussion of this subject will be brief.

3.12.3 Bench-Scale Testing

Bench-scale testing conclusions and recommendations will focus primarily on the technology's performance (i.e., ability to meet the anticipated cleanup goals for the site) and will attempt to identify critical parameters for future treatability testing, if needed. The results should include a statistical evaluation of the data and a discussion of data quality.

3.12.4 Pilot-Scale Testing

Pilot-scale testing conclusions and recommendations will focus on the technology's performance, as well as process optimization parameters that were identified. Like bench-scale treatability study reports, the results should include a statistical evaluation of the data and a discussion of data quality. If laboratory screening or bench-scale testing were also conducted, the results should be included in the final treatability study report.

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APPENDIX A

SOURCES OF TREATABILITY INFORMATION

In recent years, a wide variety of information has been developed that can assist in planning and conducting treatability studies and analyzing the data generated. Such treatability information comes from three types of sources: 1) hard copy reports, documents, or guidance; 2) electronic data bases; and 3) experienced EPA personnel. The information presented herein is not intended to be comprehensive, but rather to enable the reader to access a range of primary information sources through which other sources can be identified.

REPORTS, DOCUMENTS, AND GUIDANCE

Knowledge gained during the planning and conducting of treatability studies has begun to make its way into circulation in the form of technical resource documents, reports, and guidance manuals. The publication of information pertaining to treatability studies is recent and gaining momentum. Many of the documents available today are in draft or interim final form with revisions underway, whereas other documents are still in the planning stage and not yet available to the public. A listing of currently available primary publications that contain relevant information is provided here. Inquiries as to how to obtain these documents should be directed to the RCRA/CERCLA Hotline (1-800-424-9346).

Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C. OSWER Directive 9355-01. EPA/540/G-89/004, October 1988.

Superfund Treatability Clearinghouse Abstracts. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C. EPA/540/2-89/001, March 1989.

The Superfund Innovative Technology Evaluation Program: Technology Profiles. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response and Office of Research and Development, Washington, D.C. EPA/540/5-88/003, November 1988.

Summary of Treatment Technology Effectiveness for Contaminated Soil. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C. 1989 (in press).

ELECTRONIC DATA BASES

Interaction with available data bases can provide an additional perspective on the interpretation of results from treatability studies. The efficacy of constructing a data base that integrates pertinent elements of several existing data bases is currently being explored by the Risk Reduction Engineering Laboratory. The resulting consolidated data base would be designed to provide sufficient high-quality data for application to treatability studies conducted for different compounds within a similar class. The overall objective of developing a consolidated data base is to create a single mechanism for transferring knowledge about what does and doesn't work, based on previous studies of like contaminants.

No such consolidated data base currently exists; however, several unique data bases in various phases of development are mentioned because they contain some elements of value for evaluation of the effectiveness of a particular technology in treating different classes of contaminants.

- WERL Treatability Data Base/Superfund Treatability Data Base
- OSWER Electronic Bulletin Board System (BBS)
- Computerized On-Line Information System (COLIS)
- Alternative Treatment Technology Information Center (ATTIC)

Although this appendix highlights several of these systems, it should not be construed as a comprehensive collection of data bases. Each of the systems listed is briefly described, however, to provide the reader with a general background on the type of information that is available.

WERL Treatability Data Base/Superfund Treatability Data Base

Contact: Kenneth Dostal
(513) 569-7503

The WERL Treatability Data Base was begun under the former Water Engineering Research Laboratory (WERL) and is now maintained by the Risk Reduction Engineering Laboratory (RREL) in Cincinnati, Ohio. The purpose of the data base was to compile data on the treatability of specific organic and inorganic compounds in all types of waters and wastewaters. The data base currently contains more than 800 compounds, and more than 2500 sets of treatability data are available for approximately 300 of those compounds. The data base is available on PC disks, and the following hardware and software are needed for its use:

- IBM PC or compatible
- PC/MS DOS, Version 2.0 or greater
- 524K RAM available
- 10 cbi printer
- Monochrome or color monitor

The WERL Treatability Data Base currently has more than 1500 users throughout EPA Headquarters, the Regional offices, and other State and Federal agencies. The system is programmed in dBase III+ and is delivered on floppy disks at no charge to users. This system will also be available through COLIS (described below) in fiscal year 1990.

The WERL Treatability Data Base is currently being expanded to include treatability study data for all CERCLA site waste matrices. Called the Superfund Treatability Data Base, this component of the WERL Treatability Data Base will contain data from all treatability studies conducted under CERCLA. A repository for treatability study reports will be maintained at the Risk Reduction Engineering Laboratory in Cincinnati, Ohio.

OSWER Electronic Bulletin Board System (BBS)

Contact: James Cummings
(202) 382-4686

The OSWER Electronic Bulletin Board System was created in 1987 by the Office of Solid Waste and Emergency Response as a tool for communicating ideas and disseminating information. In addition to its message capabilities, BBS is a gateway for many Office of Solid Waste (OSW) electronic data bases. Few restrictions are set on the types of information exchanged. The BBS is intended to be available to personnel throughout OSWER, the Regional offices, the Regional laboratories, and their contractors. Restrictions on access to the BBS are few.

As mentioned earlier, BBS is a vehicle through which users can post and receive messages. Systems operators update the system with news as it becomes available. Data bases can be downloaded from or uploaded to BBS. Users must be equipped with a personal computer or a terminal, a modem, and a communications package.

Currently, the BBS has eight different components, including news and mail services and conferences and publications on specific technical areas. For example, it includes conferences on ground water and waste minimization.

Computerized On-Line Information System (COLIS)

Contact: Hugh Masters
(201) 321-6678

The Computerized On-Line Information System was started in 1980 and is housed and maintained at the Risk Reduction Engineering Laboratory in Edison, New Jersey. COLIS was not designed as a data base, but rather as an information system. It consolidates several computerized data bases developed by RREL in Cincinnati and Edison.

COLIS has been developed to accommodate any type of personal computer or microcomputer and any type of modem; no special equipment is required. Programs for searching data are provided within COLIS in a menu-type format, and the system uses standard prompt commands. COLIS is currently composed of three files: Case Histories, Library Search, and Superfund Innovative Technology Evaluation (SITE) Applications Analysis Reports (AARs).

The Case Histories file contains historical information obtained from corrective actions implemented at Superfund sites and on leaking underground storage tanks. The Library Search system is designed to provide access to special collections or research information pertaining to many RREL programs (e.g., oil and hazardous materials, underground storage tanks, soils washing, incineration, and stormwater controls). This file is under development and scheduled for implementation by December 1989. The SITE AARs file provides actual cost and performance information. It presents results from three sites for which AARs have been prepared. Additional information will be added as AARs are completed.

Information stored in this system is textual in nature instead of numerical, which permits the user's interpretation. Plans for near-term development call for the implementation of both the Aqueous Treatability Data Base and the Soils & Debris Treatability Data Base.

Alternative Treatment Technology Information Center (ATTIC)

Contact: Michael Mastracci
(202) 382-5748

The creation and development of the Alternative Treatment Technology Information Center has been overseen by ORD Headquarters. ATTIC, which is a compendium of information from many available data bases, can be accessed through the RCRA/CERCLA Hotline or the BBS. Targeted user groups for this system are RPMs, On-Scene Coordinators (OSCs), ARCS contractors, and State Superfund program personnel.

Data relevant to the use of treatment technologies in Superfund actions are collected and stored in ATTIC. It serves as a mechanism for searching other information systems and data bases for pertinent data and integrates the information found into a response to the user's query. It also includes a pointer system to refer the user to individual experts throughout the Agency.

ATTIC comprises nine different data bases including a ROD data base, soil transport and fate, a hazardous waste collection data base, a historical user file, and a technical assistance option. The system is currently made up of technical summaries from SITE program abstracts, treatment technology demonstration projects, industrial project results, and international program data.

EPA PERSONNEL

As part of a recent EPA initiative to facilitate the conduct and quality of treatability studies, the Office of Research and Development has undertaken to make human resources available to EPA Regional staff to provide the benefit of their scientific and practical expertise. The result has been the creation of the Superfund Technical Assistance Response Team (START) and complementary technology teams.

The goal of the Superfund Technical Support Task Force, which directs the START and technology teams, is to facilitate the exchange of knowledge about conducting treatability studies from personnel with treatability study experience or a substantial technical understanding of a specific treatment technology to personnel having little experience in either area. Currently, the Task Force is supporting a variety of treatability-related activities, including the development of this guide, the preparation of technology-specific protocols, drafting technology evaluation summary sheets, and compiling a list of vendors who perform treatability studies. For further details, contact Benjamin L. Blaney at the Risk Reduction Engineering Laboratory (513/569-7406).

APPENDIX B

COST ELEMENTS ASSOCIATED WITH TREATABILITY STUDIES

Section 2 of this guide describes three tiers of treatability testing: laboratory screening, bench-scale testing, and pilot-scale testing. This appendix presents the cost elements associated with the various tiers of treatability studies. In some cases, unit costs are provided, and in other cases project-specific examples are provided that lend insight into the costs of various elements of treatability studies.

Many cost elements are applicable to all levels of treatability testing, although some, such as the volume of residuals or cost of analytical services, will increase from laboratory screening to bench-scale testing to pilot-scale testing. Other cost elements (e.g., site preparation and utilities) are only applicable to pilot-scale testing. Figure 13 shows the applicability of the various cost elements to the different treatability study tiers. The following is a discussion of some of the key cost elements.

Site preparation and logistics costs include costs associated with planning and management, site design and development, equipment and facilities, health and safety equipment, soil excavation, feed homogenization, and feed handling. Costs associated with the majority of these activities are normally incurred only on mobile pilot-scale treatability studies; however, some of these cost elements, such as feed homogenization and health and safety, are seen in laboratory screening and bench-scale testing.

Vendor equipment rental is a key cost element in the performance of pilot-scale testing. Most vendors have established daily, weekly, and monthly rates for the use of their treatment systems. These charges cover wear and tear on the system, utilities, maintenance and repair, and system preparation. In some cases, vendors include their operators, personal protective equipment, chemicals, and decontamination in the rental charge. Treatment system rental charges typically run about \$5,000 to \$20,000 per week. Also, if the vendor sets up a strict timetable for testing, the client may be billed \$4000 to \$5000 per day for each day the waste is late in arriving at the facility.

Analytical costs apply to all tiers of treatability studies and have a significant impact on the total project costs. Several factors affect the cost of the analytical program, including the laboratory performing the analyses, the analytical target list, the number of samples, the required

Cost Element	Treatability Study Tier		
	Laboratory Screening	Bench-Scale	Pilot-Scale
Site Preparation (e.g., feed homogenization)	◒	◒	●
Permitting and Regulatory	◒	◒	●
Test Plan Preparation	●	●	●
Mobilization/ Demobilization	○	○	●
Vendor Equipment Rental	○	○	●
Supplies (materials)	●	●	●
Supplies (utilities)	◒	◒	●
Health and Safety	●	●	●
Field Instrumentation and Monitors	○	◒	●
Testing Equipment	◒	●	●
Materials Compatibility Testing	○	●	◒
Analytical	◒	●	●
Air Emission Treatment	○	◒	●
Effluent Treatment	◒	◒	●
Decontamination of Equipment	●	●	●
Residual Transportation	◒	◒	●
Treatment/ Disposal	◒	◒	●

○ Not applicable and/or no cost incurred.

◒ May be applicable and/or intermediate cost incurred.

● Applicable and/or high cost incurred.

Figure 13. General applicability of cost elements to various treatability study tiers.

turnaround time, QA/QC, and reporting. Analytical costs vary significantly from laboratory to laboratory, but before prices are compared, the laboratories should be properly compared. What methods will be used for sample preparation and analysis? What detection limits are needed? Does each laboratory fully understand the matrix that will be received (e.g., tarry sludge, oily soil, slag) or interference compounds that may be in the sample (e.g., sulfide)? If all information indicates that the laboratories are using the same methods and equipment and understand the objectives of the analytical program, the costs for analysis can be compared.

It is also important to be aware that some analytes cost more to analyze than others. Often, there are analytes that the investigator would like to analyze for informational purposes that may not be critical to the study. The decision to analyze for these parameters could be simple if the parameter-specific costs were known. For example, TOC analysis of soil costs about $90/sample, whereas analysis for total dioxins costs about $650/sample.

The number of samples, turnaround time, QA/QC, and reporting also affect analytical costs. Often, laboratories give discounts on sample quantities of greater than 5, greater than 10, and greater than 20 when the samples arrive in the laboratory at the same time. The laboratory also applies premium costs of 25, 50, 100, and 200 percent when analytical results are requested sooner than normal turnaround time. For example, if the cost to analyze a soil sample for mercury by cold vapor atomic absorption is $33 for a 20-working-day turnaround, the cost would escalate to $41.25 for a 10- to 15-day turnaround time, $49.50 for a 5- to 10-day turnaround time, $66 for a 48- to 96-hour turnaround time, and $99 for less than a 48-hour turnaround time. If matrix spike and matrix spike duplicates are required, the analytical cost will triple for those QA/QC samples. Also, whether the laboratory provides a cover letter with the attached data or a complete analytical report will affect the analytical costs.

Residual transportation and disposal are also important elements that must be budgeted in the performance of all treatability studies. Depending on the technology(ies) involved, a number of residuals will be generated. Partially treated effluent, scrubber water, sludge, ash, spent filter media, scale, and decontamination liquids/solids are examples of residuals that must be properly transported and treated or disposed of in accordance with all local, State, and Federal regulations. Unused feed and excess analytical sample material must also be properly managed. Typically, a laboratory will add a small fee (e.g., $5 per sample) to dispose of any unused sample material; however, the unused raw material and residuals, which could amount to a sizeable quantity of material, will cost significantly more to remove. Transportation cost for a dedicated truck (as opposed to a truck making a "milk run") is about $3.25 to $3.75 per loaded mile. Costs for treatment of inorganic wastewaters may range from $65 to $200 per 55-gallon drum. Incineration of organic-contaminated wastewaters ranges from $200 to $1000 per 55-gallon drum, and to landfill a 55-gallon drum of inorganic solids could cost between $75 and $200. Disposal facilities may also have some associated fees, surcharges, and other costs for minimum disposal, waste approval, State and local taxes, and stabilization.

APPENDIX C

TECHNOLOGY-SPECIFIC CHARACTERIZATION PARAMETERS

The tables in Appendix C contain waste feed characterization parameters specific to biological, physical/chemical, immobilization, thermal, and in situ treatment technologies. These are generally the critical waste parameters that must be established before a treatability test is conducted on the corresponding technology. These parameters should be evaluated on a site-specific basis.

Each table is divided by technology, waste matrix, parameter, and purpose of analysis. These tables are designed to assist the RPM in planning a treatability study.

TABLE 17. CHARACTERIZATION PARAMETERS FOR BIOLOGICAL TREATMENT

Treatment technology	Matrix	Parameter	Purpose and comments
General	Soils/sludges	Physical: Moisture content Field capacity pH Temperature Oxygen availability	To determine the treatability of the material and the treatment process of choice.
		Chemical: Total organic carbon (TOC) Redox potential	To determine the treatability of the material and the treatment process of choice.
		Carbon:nitrogen:phosphorus ratio	To determine mineral nutrient requirements.
		Biological: Soil biometer tests	To determine biodegradation potentials and to quantify biodegradation rates of contaminants.
		Electrolytic respirometer tests	This is an enrichment procedure used to measure oxygen uptake and biodegradation.
		Culture studies	To determine the indigenous microflora or specifically adapted microflora to be used in the inoculum during the enrichment procedure.
		Bacterial enumeration tests (e.g., spread-plate techniques)	To determine the bacterial population density in the inoculum.
		Microbial toxicity/growth inhibition tests	To determine biological activity in the laboratory.
	Liquids	Chemical: pH Dissolved oxygen (DO) Chemical oxygen demand (COD)	To determine the treatability of the material and the treatment process of choice.
		Biological: Biological oxygen demand (BOD)	To determine the treatability of the material and the treatment process of choice.
		Culture studies	To determine the indigenous microflora.
		Microbial toxicity/growth inhibition tests	To determine biological activity in the laboratory.

TABLE 18. CHARACTERIZATION PARAMETERS FOR PHYSICAL/CHEMICAL TREATMENT

Treatment technology	Matrix	Parameter	Purpose and comments
General	Soils/sludges	Physical: Type, size of debris	To determine need for pretreatment.
		Dioxins/furans, radionuclides, asbestos	To determine special waste-handling procedures.
Extraction - Aqueous - Solvent - Critical fluid - Air/steam	Soils/sludges	Physical: Particle-size distribution	To determine volume reduction potential, pretreatment needs, solid/liquid separability.
		Clay content	To determine adsorption characteristics of soil.
		Moisture content	To determine conductivity of air through soil.
		Chemical: Organics	To determine concentration of target or interfering constituents, pretreatment needs, extraction medium.
		Metals (total)	To determine concentration of target or interfering constituents, pretreatment needs, extraction medium.
		Metals (leachable)	To determine mobility of target constituents, posttreatment needs.
		Contaminant characteristics: ° Vapor pressure ° Solubility ° Henry's Law constant ° Partition coefficient ° Boiling point ° Specific gravity	To aid in selection of extraction medium.
		Total organic carbon (TOC), humic acid	To determine presence of organic matter, adsorption characteristics of soil.
		Cation exchange capacity (CEC)	To determine adsorption characteristics of soil.
		pH	To determine pretreatment needs, extraction medium.
		Cyanides, sulfides, fluorides	To determine potential for generating toxic fumes at low pH.
Chemical dehalogenation	Soils/sludges	Physical: Moisture content	To determine reagent requirements.
		Chemical: Aromatic halides	To determine concentration of target constituents, reagent requirements.
		Metals	To determine concentration of other alkaline-reactive constituents, reagent requirements.
		pH	To determine reagent requirements.
	Liquids	Chemical: Aromatic halides	To determine concentration of target constituents, reagent requirements.

(continued)

TABLE 18 (continued)

Treatment technology	Matrix	Parameter	Purpose and comments
Oxidation/ reduction	Soils/sludges	Physical: Total suspended solids	To determine the need for slurrying to aid mixing.
		Chemical: Chemical oxygen demand (COD)	To determine the presence of oxidizable organic matter, reagent requirements.
		Metals (Cr^{+3}, Hg, Pb, Ag)	To determine the presence of constituents that could be oxidized to more toxic or mobile forms.
		pH	To determine potential chemical interferences.
Flocculation/ sedimentation	Liquids	Physical: Total suspended solids	To determine reagent requirements.
		Specific gravity of suspended solids	To determine settling velocity of suspended solids.
		Viscosity of liquid	To determine settling velocity of suspended solids.
		Chemical: pH	To aid in selection of flocculating agent.
		Oil and grease	To determine need for demulsifying agents, oil/water separation.
Carbon adsorption	Liquids	Physical: Total suspended solids	To determine need for pretreatment to prevent clogging.
		Chemical: Organics	To determine concentration of target constituents, carbon loading rate.
		Oil and grease	To determine need for pretreatment to prevent clogging.
		Biological: Microbial plate count	To determine potential for biodegradation of adsorbed organics and/or problems due to clogging or odor generation.
	Gases	Physical: Particulates	To determine need for pretreatment to prevent clogging.
		Chemical: Volatile organic compounds (VOCs), sulfur compounds, mercury	To determine concentration of target constituents, carbon loading rate.
Ion exchange	Liquids	Physical: Total dissolved solids	To determine exhaustion rate of ion exchange resin.
		Total suspended solids	To determine need for pretreatment to prevent clogging.
		Chemical: Inorganic cations and anions, phenols	To determine concentration of target constituents.
		Oil and grease	To determine need for pretreatment to prevent clogging.

(continued)

TABLE 18 (continued)

Treatment technology	Matrix	Parameter	Purpose and comments
Reverse osmosis	Liquids	Physical: Total suspended solids	To determine need for pretreatment to prevent plugging of membrane.
		Chemical: Metal ions, organics	To determine concentration of target constituents.
		pH	To evaluate chemical resistance of membrane.
		Residual chlorine	To evaluate chemical resistance of membrane.
		Biological: Microbial plate count	To determine potential for biological growth inside membrane that would cause plugging.
Liquid/liquid extraction	Liquids	Physical: Solubility, specific gravity	To determine miscibility of solvent and liquid waste.
		Chemical: Contaminant characteristics: ° Solubility ° Partition coefficient ° Boiling point	To aid in selection of solvent.
Oil/water separation	Liquids	Physical: Viscosity	To determine separability of phases.
		Specific gravity	To determine separability of phases.
		Settleable solids	To determine amount of residual solids.
		Temperature	To determine rise rate of oil globules.
		Chemical: Oil and grease	To determine concentration of target constituents.
		Organics	To determine need for posttreatment.
Air/steam stripping	Liquids	Chemical: Hardness	To determine potential for scale formation.
		VOCs	To determine concentration of target constituents.
		Contaminant characteristics: ° Solubility ° Vapor pressure ° Henry's Law constant ° Boiling point	To determine strippability of contaminants.
Filtration	Liquids	Physical: Total suspended solids	To determine need for pretreatment to prevent clogging.
		Total dissolved solids	To determine need for posttreatment.

(continued)

TABLE 18 (continued)

Treatment technology	Matrix	Parameter	Purpose and comments
Dissolved air flotation	Liquids	Physical: Total suspended solids	To determine amount of residual sludge.
		Specific gravity	To determine separability of phases.
		Chemical: Oil and grease	To determine concentration of target constituents.
		VOCs	To determine need for air emission controls.
Neutralization	Liquids	Chemical: pH	To determine reagent requirements.
		Acidity/alkalinity	To determine reagent requirements.
		Cyanides, sulfides, fluorides	To determine potential for generating toxic fumes at low pH.
Precipitation	Liquids	Chemical: Metals	To determine concentration of target constituents, reagent requirements.
		pH	To determine solubility of metal precipitates, reagent requirements.
		Organics, cyanides	To determine concentration of interfering constituents, reagent requirements.
Oxidation (alkaline chlorination)	Liquids	Chemical: Cyanides	To determine concentration of target constituents, reagent requirements.
		pH	To determine suitable reaction conditions.
		Organics	To determine potential for forming hazardous compounds with excess chlorine (oxidizing agent).
		Redox potential	To determine reaction success.
Reduction	Liquids	Chemical: Metals (Cr^{+6}, Hg, Pb)	To determine concentration of target constituents, reagent requirements.
Hydrolysis	Liquids	Chemical: Organics	To determine concentration of target constituents, reagent requirements.
		pH	To determine reagent requirements.

TABLE 19. CHARACTERIZATION PARAMETERS FOR IMMOBILIZATION

Treatment technology	Matrix	Parameter	Purpose and comments
Stabilization/ solidification	Soils/sludges	Physical:	
		Description of materials	To determine waste handling methods (e.g., crusher, shredder, removal equipment).
		Particle size analysis	To determine surface area available for binder contact and leaching.
		Moisture content	To determine amount of water to add/remove in S/S mixing process.
		Density testing	To evaluate changes in density between untreated and treated waste.
		Strength testing	
		° Unconfined compressive strength	To evaluate changes in response to overburden stress between untreated and treated waste (e.g., material response to stress from cap).
		° Flexural strength	To evaluate material's ability to withstand loads over large area.
		° Cone index	To evaluate material's stability and bearing capacity.
		Durability testing	To evaluate durability of treated wastes (freeze-thaw and wet-dry durability).
		Chemical:	
		pH	To evaluate changes in leaching as function of pH.
		Alkalinity	To evaluate changes in leaching as function of alkalinity.
		Interfering compounds	To evaluate viability of S/S process. (Interfering compounds are those that impede fixation reactions, cause adverse chemical reactions, generate excessive heat; interfering compounds vary with type of S/S.)
		Indicator compounds	To evaluate performance of S/S (i.e., leaching).
		Leach testing	To evaluate performance of S/S.
		Heat of hydration	To measure temperature changes during mixing.
Vitrification	Soils/sludges	Physical:	
		Depth of contamination and water table	Technology is applied in unsaturated soils.
		Soil permeability	Dewatering of saturated soils may be possible. Technology is applied in unsaturated soils.
		Metal content of waste material and placement of metals within the waste	Greater than 5 to 15% by weight or significant amounts of metal near electrodes interfere with process.
		Combustible liquid/solid content of waste	Greater than 5 to 15% by weight interferes with process.
		Rubble content of waste	Greater than 10 to 20% by weight interferes with process.
		Void volumes	Large, individual voids (greater than 150 ft^3) impede process.

TABLE 20. CHARACTERIZATION PARAMETERS FOR THERMAL TREATMENT

Treatment technology	Matrix	Parameter	Purpose and comments
General	Soils/sludges	Physical:	
		Moisture content	Affects heating value and material handling.
		Ash content	To determine the amount of ash that must be disposed or treated further.
		Ash fusion temperature	High temperature can cause slagging problems with inorganic salts having low melting points.
		Chemical:	
		Volatile organics, semivolatile organics	Allows determination of principal organic hazardous constituents (POHCs).
		POHCs	Allows determination of destruction removal efficiency (DRE).
		Total chlorine, fluorine	To determine air pollution control devices for control of acid gases.
		Total sulfur, total nitrogen	Emissions of SO_x and NO_x are regulated; to determine air pollution devices.
		Phosphorus	Organic phosphorus compounds may contribute to refractory attack and slagging problems.
		Polychlorinated biphenyls (PCBs), dioxins (if suspected)	99.9999% DRE required for PCBs; safety considerations; incineration is required if greater than 500 ppm PCBs present.[4]
		Metals	Volatile metals (Hg, Pb, Cd, Zn, Ag, Sn) may require flue-gas treatment; other metals may concentrate in ash. Trivalent chromium may be oxidized to hexavalent chromium, which is more toxic. Presence of inorganic alkali salts, especially potassium and sodium sulfate, can cause slagging.
	Liquids	Physical:	
		Viscosity	Waste must be pumpable and atomizable.
		Total solids content	Affects pumpability and heat transfer.
		Particle-size distribution of solid phases	Affects pumpability and heat transfer.
		Heat value	Determine auxiliary fuel requirements.
		Chemical:	
		Volatile organics, semivolatile organics	Allows determination of POHCs.
		POHCs	Allows determination of DREs.
		Total chlorine, fluorine	To determine air pollution control devices for control of acid gases. Chlorine could contribute to formation of dioxins.
		Total sulfur, total nitrogen	Emissions of SO_x and NO_x are regulated; to determine air pollution devices.
		Phosphorus	Organic phosphorus compounds may contribute to refractory attack and slagging problems.
		PCBs, dioxins (if suspected)	99.9999% DRE required for PCBs; safety considerations; incineration is required if greater than 500 ppm PCBs present.[4]

(continued)

TABLE 20 (continued)

Treatment technology	Matrix	Parameter	Purpose and comments
		Metals	Volatile metals (Hg, Pb, Cd, Zn, Ag, Sn) may require flue-gas treatment; other metals may concentrate in ash. Trivalent chromium may be oxidized to hexavalent chromium, which is more toxic. Presence of inorganic alkali salts, especially potassium and sodium sulfate, can cause slagging.
Rotary kiln	Soils/sludges	Physical: Particle-size distribution	Fine particle size results in high particulate loading in rotary kiln. Large particle size may present feeding problems.
	Debris	Physical: Amount, description of materials	Oversized debris presents handling problems and kiln refractory loss.
		Presence of spherical or cylindrical wastes	Spherical or cylindrical waste can roll through kiln before combusting.
Fluidized-bed	Soils/sludges	Physical: Ash fusion temperature	For materials with a melting point less than 1600°F, particles melt and become sticky at high temperatures, which causes defluidization of the bed.
		Ash content	Ash contents greater than 65% can foul the bed.
		Bulk density	As density increases, particle size must be decreased for sufficient heat transfer.

TABLE 21. CHARACTERIZATION PARAMETERS FOR IN SITU TREATMENT

Treatment technology	Matrix	Parameter	Purpose and comments
Vapor extraction - Vacuum extraction - Steam-enhanced - Hot-air-enhanced	Soils/sludges	Physical: Vapor pressure of contaminants	To estimate ease of volatilization.
		Soil permeability, porosity, particle-size distribution	To determine if the soil matrix will allow adequate air and fluid movement.
		Depth of contamination and to water table	To determine relative distance; technology applicable in vadose zone.
Solidification/stabilization (undisturbed) - Pozzolanic - Polymerization - Precipitation	Soils/sludges	Physical: Presence of subsurface barriers (e.g., drums, large objects, debris, geologic formations	To assess the feasibility of adequately delivering and mixing the S/S agents.
		Depth to first confining layer	To determine required depth of treatment.
Soil flushing - Steam/hot water - Surfactant - Solvent	Soils/sludges	Physical: Presence of subsurface barriers (e.g., drums, large objects, debris, geologic formations)	To assess the feasibility of adequately delivering the flushing solution.
		Hydraulic conductivity	To assess permeability of the soils.
		Moisture content (for vadose zone)	To calculate pore volume to determine rate of treatment.
		Soil/water partition coefficient	To assess removal efficiency and to correlate between field and theoretical calculations.
		Octanol/water partition coeffcient	To assess removal efficiency and to correlate between field and theoretical calculations.
		CEC	To evaluate potential for contaminant flushing.
		Alkalinity of soil	To estimate the likelihood of precipitation.
		Chemical: Major cation/anions present in soil	To estimate the likelihood of precipitation; to estimate potential for plugging of pore volumes.
Vitrification	Soils/sludges	Physical: Depth of contamination and water table	Technology is only applied in the unsaturated zone.
Radio-frequency heating and direct-current heating	Soils/sludges	Physical: Depth of contamination and water table	Technology is only applied in the unsaturated zone.
		Presence of metal objects	Presence of metal objects precludes application.
Electrokinetics	Soils/sludges	Physical: Hydraulic conductivity	Technology applicable in zones of low hydraulic conductivity.
		Depth to water table	Technology applicable in saturated soils.
		Chemical: Presence of soluble metal contaminants	Technology applicable to soluble metals, but not organics and insoluble metals.

(continued)

TABLE 21 (continued)

Treatment technology	Matrix	Parameter	Purpose and comments
Microbial degradation - Aerobic	Soils/sludges	Physical: Permeability of soil	To determine ability to deliver nutrients or oxygen to matrix and to allow movement of microbes.
		Chemical/biological: Contaminant concentration and toxicity	To determine viability of microbial population in the contaminated zone.
- Anaerobic	Soils/sludges	Chemical/biological: Contaminant concentration and toxicity	To determine viability of microbial population in the contaminated zone.
Adsorption (trench)	Soils/sludges	Physical: Depth of contamination and water table	Technology applicable in saturated zone.
		Horizontal hydraulic flow rate	To determine if ground water will come into contact with adsorbent.

APPENDIX D

STANDARD ANALYTICAL METHODS FOR CHARACTERIZING WASTES

The tables in Appendix D contain the analytical methods necessary for evaluation of the physical and chemical waste feed characteristics identified in Appendix C. The waste matrices are divided into soils/sludges, liquids, and gases. The methods listed are standard EPA-approved procedures, when such exist. A description of each test and a reference for its method are also included.

TABLE 22. SOILS/SLUDGES: CHARACTERIZATION OF PHYSICAL PROPERTIES

Physical parameter	Description of test	Method	Reference*
Ash content	Electric muffle furnace	ASTM D 3174 (coal)	a
		ASTM E 830 (RDF-3)	a
Ash fusibility	Combustion furnace, pyrometer	ASTM E 953 (RDF-3)	a
Atterberg limits	Liquid limit, plastic limit, plasticity index	ASTM D 4318	a
Bulk density	Drive cylinder method	ASTM D 2937	a
	Sand-cone method	ASTM D 1556	a
	Nuclear method	ASTM D 2922	a
	Rubber ballon method	ASTM D 2167	a
	Hydraulic cement stabilized waste	ASTM C 188 (cement)	a
Cation exchange capacity (CEC)	Ammonium acetate	Method 9080	b
	Sodium acetate	Method 9081	b
Clay content	X-ray diffraction	Not standard	c
Corrosivity	Corrosivity toward steel	Method 1110	b
Durability	Freeze-thaw	ASTM D 560	a
	Wet-dry	ASTM D 559	a
Free liquids	Paint filter test	Method 9095	b
Gross calorific value	Bomb calorimeter	ASTM E 711 (RDF-3)	a
	Adiabatic bomb calorimeter	ASTM D 2015	a
	Isothermal bomb calorimeter	ASTM D 3286 (coal)	a
Ignitability	Pensky-Martens closed-cup	Method 1010	b
	SetaFlash closed-cup	Method 1020	b
Moisture content	Drying oven at 110°C	ASTM D 2216	a
	In situ, nuclear method	ASTM D 3017	a
Oxidation/reduction potential (E_h) of leachate	Electrometric	ASTM D 1498	a
Particle size distribution	Hydrometer and sieve	ASTM D 422	a

(continued)

TABLE 22 (continued)

Physical parameter	Description of test	Method	Reference*
Permeability	Falling head	Method 9100	b
	Constant head	Method 9100	b
Pore volume	Mercury intrusion porosimetry	ASTM D 4404	a
Reactivity	To determine hydrogen cyanide released	Section 7.3.3.2	b
	To determine hydrogen sulfide released	Section 7.3.4.1	b
Soil classification/profile	SCS-Engineering purposes	ASTM D 2487	a
	SCS-Visual/manual procedure	ASTM D 2488	a
Sorptive capacity	24-h batch-type distribution ratio	ASTM ES10	a
Specific gravity	Pycnometer	ASTM D 854	a
Temperature	Ambient, thermometer	-	-
Toxicity	Extraction procedure (EP) toxicity test method	Method 1310	b
	Toxicity characteristic leaching procedure (TCLP)	Method 13XX	d
Unconfined compressive strength	-	ASTM D 2166	a

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[*] All references for Appendix D tables appear at the end of Table 27.

TABLE 23. SOILS/SLUDGES: CHARACTERIZATION OF CHEMICAL PROPERTIES

Chemical parameter	Description of test	Method	Reference*
Aromatic volatile organics	Gas chromatography	Method 8020	b
Base, neutral, and acid compounds (BNA)	Gas chromatography/mass spectrometry	Method 8270	a
Chemical oxygen demand (COD) of leachate	Titrimetric	Method 410.1-.3	e
	Colorimetric	Method 410.4	e
Chlorinated hydrocarbons	Gas chromatography	Method 8120	b
Chlorine/chloride	Potentiometric titration	ASTM E 776A (RDF-3)	a
	Volhard titration	ASTM E 776B (RDF-3)	a
Cyanide	Total and amenable, colorimetric	Method 9010	b
Dioxins/furans	Gas chromatography/mass spectrometry	Method 8280	b
Fluorides	Bomb combustion/ion selective electrode	ASTM D 3761	a
Halogenated volatile organics	Gas chromatography	Method 8010	b
Humic acid	Titrimetric	Not standard	f
Major and minor oxides	Atomic absorption spectrophotometry	ASTM D 3682 (coal)	a
	Absorption spectrophotometry	ASTM D 2795 (coal)	a
	X-ray fluorescence	ASTM D 4326 (coal)	a
Metals	ICP atomic emission spectroscopy	Method 6010	b
	Atomic absorption	Method 7000 series	b
Nonhalogenated volatile organics	Gas chromatography	Method 8015	b

(continued)

TABLE 23 (continued)

Chemical parameter	Description of test	Method	Reference*
Oil and grease	Oil and grease extraction method for sludge samples	Method 9071	b
Organochlorine pesticides/PCBs	Gas chromatography	Method 8080	b
pH	Soil pH	Method 9045	b
Phenols	Gas chromatography	Method 8040	b
Polynuclear aromatic hydrocarbons (PAHs)	Gas chromatography	Method 8100	b
	High-performance liquid chromatography	Method 8310	b
Radionuclides	Alpha-emitting radium isotopes	Method 9315	b
	Gross alpha and gross beta	Method 9310	b
	Radium-226	ASTM D 3454	a
	Radium-228	Method 9320	b
Sulfides	Titrimetric	Method 9030	b
Sulfur content	High-temperature combustion	ASTM D 4239 (coal)	a
	Eschka method	ASTM D 3177A (coal)	a
		ASTM E 775A (RDF-3)	a
	Bomb washing	ASTM D 3177B (coal)	a
		ASTM E 775B (RDF-3)	a
Total Kjeldahl nitrogen	Kjeldahl	ASTM D 3179 (coal)	a
	Kjeldahl-Gunning	ASTM E 778 (RDF-3)	a
	Acid titration	ASTM E 778 (RDF-3)	a
Total organic carbon (TOC)	Combustion	Method 9060	b
Total organic halides (TOX)	Oxidation/titration	Method 9020	b
	Neutron activation analysis	Method 9022	b
Volatile organics	Gas chromatography/mass spectrometry	Method 8240	b

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[*] References for all Appendix D tables appear at the end of Table 27.

TABLE 24. LIQUIDS: CHARACTERIZATION OF PHYSICAL PROPERTIES

Physical parameter	Description of test	Method	Reference*
Color	Colorimetric, ADMI	Method 110.1	e
	Colorimetric, Pt-Co	Method 110.2	e
	Spectrophotometric	Method 110.3	e
Conductance	Specific	Method 120.1	e
Corrosivity	Corrosivity toward steel	Method 1110	b
Flammability limits	Upper and lower	ASTM E 918	a
Hardness, total	Colorimetric, EDTA	Method 130.1	e
	Titrimetric, EDTA	Method 130.2	e
Heat value	Bomb calorimeter	ASTM E 711	a
Ignitability	Pensky-Martens closed-cup	Method 1010	b
	SetaFlash closed-cup	Method 1020	b
Odor	Threshold odor (consistent series)	Method 140.1	e
Oxidation/reduction potential (E_h)	Electrometric	ASTM D 1498	a
Reactivity	To determine hydrogen cyanide	Section 7.3.3.2	b
	To determine hydrogen sulfide	Section 7.3.4.1	b
Solids	Filterable, gravimetric	Method 160.1	e
	Nonfilterable, gravimetric	Method 160.2	e
	Total, gravimetric	Method 160.3	e
	Volatile gravimetric	Method 160.4	e
	Settleable matter	Method 160.5	e
Specific gravity of liquid phases	Hydrometer	ASTM D 891A	a
	Pycnometer	ASTM D 891B	a
Specific gravity of solid phases	Pycnometer	ASTM D 854	a
Temperature	Thermometric	Method 170.1	e

(continued)

TABLE 24 (continued)

Physical parameter	Description of test	Method	Reference*
Toxicity	Extraction procedure (EP) toxicity test method	Method 1310	b
	Toxicity characteristic leaching procedure (TCLP)	Method 13XX	d
Turbidity	Nephelometric	Method 180.1	e
Viscosity	Kinematic viscosity of volatile and reactive liquids	ASTM D 4486	a
	Kinematic viscosity of transparent and opaque liquids	ASTM D 445	a

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[*] References for all Appendix D tables appear at the end of Table 27.

TABLE 25. LIQUIDS: CHARACTERIZATION OF CHEMICAL PROPERTIES

Chemical parameter	Description of test	Method	Reference*
Acidity	Titrimetric	Method 305.1	e
Alkalinity	Titrimetric	Method 310.1	e
Aromatic volatile organics	Gas chromatography	Method 8020	b
Base, neutral, and acid (BNA) compounds	Gas chromatography/mass spectrometry	Method 8270	b
Chemical oxygen demand (COD)	Titrimetric	Methods 410.1-.3	e
	Colorimetric	Method 410.4	e
Chlorinated hydrocarbons	Gas chromatography	Method 8120	b
Cyanide, total and amenable	Colorimetric, manual	Method 9010	b
	Colorimetric, automated UV	Method 9012	b
Dioxins/furans	Gas chromatography/mass spectrometry	Method 8280	b
Halides	Bromide; titrimetric	Method 320.1	e
	Chloride; colorimetric, AA	Methods 325.1, .2	e
	titrimetric	Method 325.3	e
	Fluoride; colorimetric,	Method 340.1	e
	potentiometric,	Method 340.2	e
	colorimetric	Method 340.3	e
	Iodide; titrimetric	Method 345.1	e
Hardness, total	Colorimetric, EDTA	Method 130.1	e
	Titrimetric, EDTA	Method 130.2	e
Halogenated volatile organics	Gas chromatography	Method 8010	b
Metals	ICP atomic emission spectroscopy	Method 6010	b
	Atomic absorption	Method 7000 series	b
Nitrogen	Ammonia	Methods 350.1-.3	e
	Kjeldahl, total	Methods 351.1-.4	e
	Nitrate	Method 352.1	e
	Nitrate-nitrite	Methods 353.1-.3	e
	Nitrite	Method 354.1	e

(continued)

TABLE 25 (continued)

Chemical parameter	Description of test	Method	Reference*
Nonhalogenated volatile organics	Gas chromatography	Method 8015	b
Oil and grease,	Total recoverable, gravimetric with extraction	Method 9070	b
Organochlorine pesticides/PCBs	Gas chromatography	Method 8080	b
pH	Electrometric	Method 9040	b
Phenolics	Spectrophotometric	Method 9065	b
	Colorimetric	Method 9066	b
	Spectrophotometric, MBTH	Method 9067	b
Phosphorus	All forms; colorimetric	Methods 365.1-.3	e
	Total; colorimetric	Method 365.4	e
Polynuclear aromatic hydrocarbons (PAHs)	Gas chromatography	Method 8100	b
	High-performance liquid chromatography	Method 8310	b
Radionuclides	Alpha-emitting radium isotopes	Method 9315	b
	Gross alpha and gross beta	Method 9310	b
	Radium-226	ASTM D 3454	a
	Radium-228	Method 9320	b
Sulfate	Colorimetric, chloranilate	Method 9035	b
	Colorimetric, methylthymol blue	Method 9036	b
	Turbidimetric	Method 9038	b
Sulfides	Titrimetric	Method 9030	b
Total organic carbon (TOC)	Flame ionization	Method 9060	b
Total organic halides (TOX)	Oxidation/titration	Method 9020	b
	Neutron activation	Method 9022	b
Total petroleum hydrocarbons	IR spectrophotometric	Method 418.1	e
Volatile organics	Gas chromatography/mass spectrometry	Method 8240	b

* All references for Appendix D tables appear at the end of Table 27.

TABLE 26. GASES/VAPORS: CHARACTERIZATION OF PHYSICAL PROPERTIES

Physical parameter	Description of test	Method	Reference*
Flammability	Upper, lower limits	ASTM E 918	a
Moisture content	Volumetric, gravimetric	Method 4	g
Opacity	Visual determination of opacity	Method 9	g
Particulate	Front half	Method 5	g
	Filterable and condensible back half	Method 5	g
	Instack with thimble and filter	Method 17	g

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[*] All references for Appendix D tables appear at the end of Table 27.

TABLE 27. GASES/VAPORS: CHARACTERIZATION OF CHEMICAL PROPERTIES

Chemical parameter	Description of test	Method	Reference
Acid mist (H_2SO_4, SO_2)	Barium-thorin titration	Method 8	g
Aldehydes	High performance liquid chromatography	T05	h
Ammonia	Titration/Nesslerization	Method 350.2	e
Arsenic	Atomic absorption	Method 108	i
Asbestos	TEM	7402	j
Beryllium	Atomic absorption	Method 104	i
Carbon monoxide	Gas chromatography/flame ionization detection	Method 10	g
Chlorine	Ion chromatography	Method 300.0	e
Fluoride	Specific ion electrode	Method 13B	g
Hexane	Gas chromatography/mass spectrometry--		
	Tenax, VOST	Method 5040	b
	Canister	T014	h
Hydrocarbons	Gas chromatography/mass spectrometry--		
	Tenax VOST	Method 5040	b
	Canister	T014	h
Hydrogen sulfide (H_2S)	Iodometric titration	Method 11	g
Lead	Atomic absorption	Method 12	g
Mercury	Atomic absorption	Method 101	i
Metals	ICP atomic emission spectroscopy	Method 6010	b
Nitrogen oxides (NO_x)	Colorimetric Ion chromatography	Method 7 Method 7A	g g
Oxygen, carbon dioxide, carbon monoxide (O_2, CO_2, CO)	Orsat analyzer	Method 3	g

(continued)

TABLE 27 (continued)

Chemical parameter	Description of test	Method	Reference
Pesticides/PCBs	Gas chromatography/electron-capture detection	T04	h
Phenols	High-performance liquid chromatography	T08	h
Polynuclear aromatic hydrocarbons	Gas chromatography/mass spectrometry	T013	h
Semivolatile organics	Gas chromatography/mass spectrometry	Method 8270	b
Sulfides (H_2S, COS, CS_2)	Gas chromatography/flame photometry	Method 15	g
Sulfur content, total	Hydrogenolysis and rateometric colorimetry	ASTM D 4468	a
Sulfur dioxide (SO_2)	Barium-thorin titration	Method 6	g
Toluene	Gas chromatography/mass spectrometry--		
	Tenax, VOST	Method 5040	b
	Canister	T014	h
Vinyl chloride	Gas chromatography/mass spectrometry--		
	Canister	T014	h
Volatile organics	Gas chromatography/mass spectrometry--		
	Tenax, VOST	Method 5040	b
	Canister	T014	h
Xylene, toluene	Gas chromatography/mass spectrometry--		
	Tenax, VOST	Method 5040	b
	Canister	T014	h

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[a] American Society for Testing and Materials. Annual Book of ASTM Standards. November 1987.

[b] U.S. Environmental Protection Agency. Test Methods for Evaluating Solid Waste. Third Edition. SW-846, 1986.

[c] Leimer, H. W., G. M. Mason, and L. K. Spackman. Mineralogic Characterization of a Chattanooga Shale Core From Central Tennessee. November 1984.

TABLE 27 (continued)

[d] 40 CFR 268; Appendix I; 51 FR 40636, November 7, 1986.

[e] U.S. Environmental Protection Agency. Methods for the Chemical Analysis of Water and Wastes. EPA-600/4-79-020. March 1983.

[f] American Society of Agronomy, Inc. Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties. 2nd Edition. 1982.

[g] 40 CFR 60; Appendix A, July 1988.

[h] U.S. Environmental Protection Agency. Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. EPA-600/4-84-041. April 1984.

[i] 40 CFR 61; Appendix B, July 1986.

[j] NIOSH manual of Analytical Methods, 3rd ed. February 1984.

GLOSSARY

This glossary defines terms used in this guide. The definitions apply specifically to the treatability study process and may have other meanings when used in different contexts. Underlined words or concepts within a definition are defined elsewhere in the glossary.

aerobes--Microorganisms that cannot grow or survive in the absence of oxygen.

alternative--A potentially applicable remedial treatment technology or treatment train. Alternatives are developed and screened during scoping of the RI/FS and throughout the RI/FS process. Alternatives are investigated by performing treatability studies and selected as remedies after a detailed analysis of each alternative is conducted.

anaerobes--Microorganisms that cannot survive or are inhibited in the presence of oxygen.

applicable or relevant and appropriate requirement (ARAR)--Federal or State requirements that are legally applicable to remedial actions at CERCLA sites or, if not legally applicable, the use of which is both relevant and appropriate under the circumstances. ARARs may be chemical-, location-, or action-specific.

aquifer--A porous, underground rock formation, often composed of limestone, sand, or gravel, that is bounded by impervious rock or clay and can store water.

bench-scale testing--A treatability study designed to provide quantitative information for the evaluation of a technology's performance for an operable unit. A bench-scale study serves to verify that the technology can meet the anticipated ROD cleanup goals and provides information in support of remedy evaluation.

biological treatment--A treatment process that uses microorganisms to break down toxic organic waste contaminants into simple less-toxic compounds.

biotoxicity--Toxic to flora and fauna.

chemical treatment--A treatment process that alters the chemical structure of a toxic waste contaminant to reduce the waste's toxicity, mobility, or volume.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)--A Federal law passed in 1980 and amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA), which created a special tax on crude oil and commercial chemicals that supports the Hazardous Substance Response Trust Fund or "Superfund." The EPA can use the money in Superfund to investigate and clean up abandoned or uncontrolled hazardous waste sites. Under CERCLA, the EPA can either pay for the site cleanup itself or take legal action to force the parties responsible for the contamination to pay for the cleanup.

containment--Response actions that involve construction of a barrier to prevent the migration of contaminated wastes.

Contract Laboratory Program (CLP)--Laboratories contracted by EPA to analyze CERCLA site waste samples by established CLP protocols and procedures.

corrosivity--One of the four hazardous waste characteristics defined under RCRA (40 CFR 261.22). A waste is corrosive if it or its leachate has a pH less than or equal to 2 or greater than or equal to 12.5 or corrodes steel (SAE 1020) at a rate greater than 6.35 mm per year at 55°C.

data quality objectives (DQOs)--The sum of characteristics of a data set that describe its utility for satisfying a given purpose. Characteristics may be precision, accuracy, completeness, representativeness, and comparability, but they may also include experimental design and statistical confidence issues. The objectives for data quality, DQOs are established before the study is conducted.

debris--Naturally occurring materials of geologic origin (such as tree stumps and vegetation) or man-made materials (such as concrete blocks, cloth, empty drums, and tires) that, because of their size, shape, or composition, present nonstandard, unique treatability problems at CERCLA sites.

detailed analysis of alternatives--A comparative analysis of all remedial alternatives that have successfully completed the technology screening phase. Each alternative is assessed against EPA's nine evaluation criteria before final remedy selections are made.

development and screening of alternatives--The identification and screening of potentially applicable treatment technologies for remedy selection.

effluent--Treated liquid waste or wastewaters exiting a treatment unit.

exclusion zone--Area of site possessing the highest concentration of contaminants, also called the "hot" zone.

extraction procedure (EP) toxicity--One of the four hazardous waste characteristics defined under RCRA (40 CFR 261.24). A waste is EP toxic if an extract from the waste is found to contain concentrations of certain metals and pesticides in excess of those listed in RCRA.

feasibility study (FS)--The analytical part of the RI/FS process, the FS serves as the mechanism for the development, screening, and detailed evaluation of potentially applicable treatment technologies. The success of the FS is highly dependent on the data generated in the RI.

flammability--The capacity to support combustion.

gas--A fluid substance possessing neither definite shape nor volume at standard temperature and pressure (STP). (Oxygen and nitrogen are gases at STP.)

Hazardous and Solid Waste Amendments (HSWA)--The 1984 amendments to the Resource Conservation and Recovery Act (RCRA) of 1976. HSWA established strict limits on the land disposal of hazardous waste.

hazardous substance--Any substance that poses a hazard to human health or the environment when improperly managed.

hazardous waste--Any solid, liquid, or gaseous waste listed in 40 CFR Part 261 or that exhibits the characteristics of ignitability, corrosivity, reactivity, or EP toxicity as defined under RCRA (see 40 CFR 261.3).

ignitability--One of the four hazardous waste characteristics defined under RCRA (40 CFR 261.21). A waste is ignitable if it has any of the following properties:

1) It is a liquid with a flash point of less than 60°C.
2) It is a nonliquid capable of causing a fire through friction, absorption of moisture, or spontaneous chemical changes at standard temperature and pressure (STP).
3) It is an ignitable compressed gas.
4) It is an oxidizer.

in situ treatment--The process of treating a contaminated matrix (soil, sludge, or ground water) in place. In situ processes may use physical, chemical, thermal, or biological technologies to treat the site.

influent--Untreated liquid waste or wastewater entering a treatment unit.

laboratory screening--A treatability study designed to establish the validity of an alternative for treating an operable unit and to identify parameters for investigation in later bench- and pilot-scale testing.

leachate--The liquid that results when water moves through solid waste materials and dissolves components of those materials.

lead agency--The Federal or State agency having primary responsibility and authority for planning and executing remediation at a CERCLA site.

liquid--Pumpable material of naturally occurring or man-made origin possessing a relatively fixed volume and a solids content of less than 10 percent.

mobility--The ability of a contaminant to migrate from its source.

National Priorities List (NPL)--EPA's priority list of uncontrolled hazardous waste sites identified for evaluation and possible remediation under Superfund. The NPL, which is updated at least once a year, is based on the score a site receives in the EPA's Hazard Ranking System. (See 40 CFR Part 300, Appendices A and B.)

nine evaluation criteria--A set of criteria developed by EPA that serve as the basis for conducting detailed analyses of remedial alternatives during the FS. The evaluation criteria implement statutory requirements under CERCLA and other technical and policy considerations that EPA has found to be important in the evaluation of remedial alternatives. These nine evaluation criteria are as follows:

1) Overall protection of human health and the environment
2) Compliance with ARARs
3) Long-term effectiveness and permanence
4) Reduction of toxicity, mobility, or volume
5) Short-term effectiveness
6) Implementability
7) Cost
8) State acceptance
9) Community acceptance

On-Scene Coordinator (OSC)--The Federal official at a CERCLA site who is responsible for coordinating immediate, short-term removal actions that address the release or threatened release of a hazardous substance.

operable unit--An individual remedial activity that constitutes one part of an overall site cleanup.

performance goal--A predetermined level of effectiveness that a treatment technology seeks to attain. Performance goals are set in terms of the percentage reduction in toxicity, mobility, or volume of a waste and its contaminants.

physical treatment--A treatment process that alters the physical structure of a toxic waste contaminant to reduce the waste's toxicity, mobility, or volume.

pilot-scale testing--A treatability study designed to provide the detailed cost and design data required to optimize a treatment technology's performance and to provide information in support of remedy implementation.

preliminary assessment--The process of collecting and reviewing initially available information about a known or suspected hazardous waste site or release.

priority pollutants--Chemical compounds that, because of their persistence, toxicity, and potential for exposure to organisms, have been listed as "toxic pollutants" by the 1977 amendments to the Clean Water Act.

protocol--A plan for conducting a scientific experiment or study.

qualitative--An analysis in which some or all of the components of a sample are identified.

quality assurance (QA)--Duplication of all or a portion of the analytical tests conducted to ensure that the desired levels of accuracy and precision are obtained.

quality control (QC)--Duplication of a portion of the analytical tests performed to estimate the overall quality of the results and to determine what, if any, changes must be made to achieve or maintain the required level of quality.

quantitative--An analysis in which the amount of one or more components of a sample is determined.

reactivity--One of the four hazardous waste characteristics defined under RCRA (40 CFR 261.23). A waste is reactive if it is unstable or undergoes rapid or explosive chemical reactions when exposed to water, heat, or extremes of pH.

Record of Decision (ROD)--A public document, signed by the lead agency and any RPs, that explains which remedial alternative(s) will be used at a particular CERCLA site. The ROD is based on data generated during the site characterization and treatability study phases of the RI/FS and on consideration given to public comments and State and community concerns.

remedial action (RA)--The actual construction or implementation phase that follows the remedial design of the selected alternative at a CERCLA site.

remedial design (RD)--The engineering phase that follows the signing of a ROD when technical drawings and specifications for a site remedial action are developed.

remedial investigation (RI)--The investigative part of the RI/FS process, the RI serves as the mechanism for site and contaminant characterization and for conducting treatability studies on the potentially applicable treatment technologies identified in the feasibility study.

remedial investigation/feasibility study (RI/FS)--The Superfund program's methodology for characterizing the nature and extent of risks posed by CERCLA sites and for identifying and evaluating potential remedial alternatives for those sites. The process is divided into two parts (the remedial investigation and the feasibility study), which are conducted concurrently; data collected in one part influence the tasks performed in the other part and visa versa.

Remedial Project Manager (RPM)--The EPA or State official responsible for overseeing remedial actions at a CERCLA site.

remedy selection--The remedial alternative(s) identified in the ROD for CERCLA site cleanup.

residual--The product or byproduct of a treatment process.

Resource Conservation and Recovery Act (RCRA)--A 1976 Federal law that established a regulatory system to track hazardous substances from the time of generation to disposal. Designed to prevent new CERCLA sites from ever being created, RCRA requires the use of safe and secure procedures in the treatment, transport, storage, and disposal of hazardous wastes. RCRA was amended in 1984 by the Hazardous and Solid Waste Amendments (HSWA).

responsible party (RP)--A person(s) or company(ies) that the EPA has determined to be responsible for, or to have contributed to, the contamination at a site.

saturated zone--A subsurface zone in which water fills the interstices and is under pressure greater than or equal to that of the atmosphere.

scoping--The initial phase of site remediation during which possible site actions and investigative activities are identified.

site characterization--The collection and analysis of field data to determine to what extent a site poses a threat to the environment and to begin developing potential remedial alternatives.

site inspection--The collection of waste site data to determine the extent and severity of hazards posed by the site. The data will be used to score the site, using the EPA's Hazard Ranking System, and to determine if it presents an immediate threat that requires prompt removal action.

sludge--Pumpable material of naturally occurring or man-made origin possessing a relatively fixed volume and a moisture content ranging from 15 to 90 percent.

soil--Nonpumpable, naturally occurring material primarily of geologic origin and possessing a fixed volume and a moisture content of less than 15 percent. Soil includes sand, silt, loam, and clay.

solidification--The process of converting a contaminated soil, sludge, or liquid waste into a solid monolithic product that is more easily handled and that reduces the volatilization and leaching of contaminants from the waste.

stabilization--The process of reducing the hazardous potential of a waste by chemically or physically converting the toxic contaminants into their least mobile or reactive form.

Superfund--The common name used for the Hazardous Substance Response Trust Fund created by CERCLA.

Superfund Amendments and Reauthorization Act (SARA)--A 1986 Federal law that amended the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980.

Superfund Innovative Technology Evaluation Program (SITE)--A 1986 program established by the EPA's Office of Solid Waste and Emergency Response (OSWER) and Office of Research and Development (ORD) to promote the development and use of innovative treatment technologies during CERCLA response actions.

technology screening--The process of collecting technical information on potentially applicable treatment technologies and determining which technologies to retain as alternatives for consideration in the FS.

thermal treatment--A treatment process that is designed to oxidize hazardous organic substances to carbon dioxide and water.

tier--One of the three levels of treatability testing (i.e., laboratory screening, bench-scale testing, or pilot-scale testing).

treatability study--The testing of a remedial alternative in the laboratory or field to obtain data necessary for a detailed evaluation of its feasibility.

treatability study sample exemption--A Federal regulation set forth in 40 CFR 261.4(f) that excludes treatability studies conducted offsite from most management and permitting requirements under RCRA.

treatment train--A complete treatment process that includes pre-treatment, primary treatment, residuals and side-stream treatments, and post-treatment considerations.

unit operation--One treatment technology that is a part of a larger treatment train.

unsaturated zone--A subsurface zone containing water below atmospheric pressure and gases at atmospheric pressure. Also known as the vadose zone.

vadose zone--A subsurface zone containing water below atmospheric pressure and gases at atmospheric pressure. Also known as the unsaturated zone.

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